

Information Circular No. 61

by

Columbus
2005



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**CONVERSION OF THE OHIO OIL- AND GAS-WELL
TOWNSHIP-LOCATION MAPS TO A GEOGRAPHIC
INFORMATION SYSTEM: HISTORY AND METHODOLOGY**

by

James McDonald, Lawrence H. Wickstrom, Christian D. Steck, and Joseph G. Wells

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ABSTRACT

The Ohio Department of Natural Resources, Division of Geological Survey, with cooperation from the Division of Oil and Gas (now part of the Division of Mineral Resources Management), has converted oil- and gas-well location maps for the state, from paper and mylar township-based spot maps, to digital files. The locations and basic attributes of approximately 217,000 wells have been captured. The project was initiated primarily to provide the Division of Geological Survey and the public with a consistent set of coordinates for all the oil and gas wells in the state, contained in one master set of maps and digital files. Additional project benefits include enhanced readability of the well-spot maps, a new method of archiving this information, and a basis for automation of processes involving these data.

More than 250,000 oil and gas wells have been drilled in Ohio since at least 1860. This long and prolific history has led to much variability in the oil and gas records in the Division of Geological Survey's files. Through the course of this project, it was necessary to investigate the origins of many of the well records. Thus, the conversion of the oil- and gas-well spot maps also grew to include documenting the history of these maps and records.

An accurate digital base map containing all land subdivisions of the state had to be compiled. Digitization and data-entry specifications were then developed for accurate capture of well locations and attributes from the existing maps. Error checking and file correction completed the process.

The initial products of this project include (1) digital graphics files of well locations to replace the mylar and paper well-spot maps, (2) a new digital tabular database containing all the wells found on the maps, and (3) a highly accurate base map for the State of Ohio. In addition, the wells were assigned unique identification numbers using the American Petroleum Institute well-identification numbering system. The database and digital graphics files contain the coordinates of all the wells, plus up to seven attributes per well. The digital oil- and gas-well spot maps and database are the foundation of an overall effort to create an integrated geographic information system for all oil- and gas-well information in the State of Ohio.

INTRODUCTION

The Ohio Division of Geological Survey (ODGS)¹ has completed a project to digitally capture the locations and basic attributes of all located oil and gas wells in the State of Ohio. The project began in April 1996 and was completed

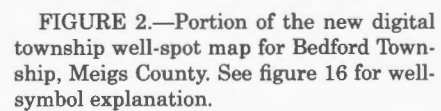
when the final data were released to the public in September 1997. Three significant products resulted from this project: (1) new digital oil- and gas-well location maps for all townships in the state, (2) a computer database containing all oil- and gas-well-location coordinates and other basic well-related information, and (3) a new digital base map for the state that includes all original land subdivisions. Included in these products are 1,355 digital township well-location files containing approximately 217,000 individual well locations. An additional significant result was the assignment of unique well-identification numbers. This project is part of an overall plan to convert most of the geologic data at the ODGS into an integrated geographic information system (GIS).

At the start of this project, staff of the ODGS Geologic Records Center and the Petroleum Geology Group generally believed that they had a good understanding of the well-location-map files and well-data records. However, through the course of the project the staff was constantly surprised to discover additional types of discrepancies and errors in the maps and data files. These discoveries prompted the staff to further research the original sources for the data and maps, which have long been taken for granted. Thus, in addition to the planned products of this project, a new understanding of the history of the ODGS oil- and gas-well records has been gained.

There are many benefits to having the oil- and gas-well information in digital format. It allows for faster and more efficient archiving, access, and analysis of the data. These reasons were a driving force in the conversion of the well-spot maps from paper and mylar to digital representations. However, there was also a near-desperate need to convert the existing well-spot maps into the digital realm. Well locations had been hand spotted on paper and mylar base maps since the 1950's. By the 1990's, the maps had deteriorated owing to constant use and age. Many of the maps were brittle and had developed folds, creases, and tears. Further, as new information was added to the maps, older information ostensibly was erased to ensure cartographic readability (fig. 1). In the process, base-map information also was erased. For these and other reasons, many of the original maps were becoming unreadable. The ODGS had recreated some of the most damaged maps by hand and at a great expense of labor. If the township well-spot maps had not been converted to digital form, many more maps would have to be redrafted. Digital conversion of the maps has eliminated the need to erase information and ensures map readability (fig. 2).

Easier public access and faster analysis of data also were driving forces in the digital conversion of the oil- and gas-well data. Today, oil- and gas-well-location data files are accessible via the Internet for public use. Previously, persons desiring digital well information had to first request the

¹Acronyms used in this report are listed in Appendix F.



paper records from the ODGS Geologic Records Center and then convert the data into electronic form themselves. This situation led to many companies and individuals performing duplicative data-entry tasks, using different formats. Today, anyone can download the most recent version of the data as soon as it is available, all in a consistent format that allows for easier manipulation and analysis.

The information that is used to spot the well location and ancillary information on the map comes from original well-permit applications that are filed with the Ohio Division of Mineral Resources Management (DMRM)². These permit applications are also recorded on well cards at the ODGS Geologic Records Center. Prior to digital conversion of well records, working with the oil- and gas-well information required tedious pulling and refiling of mylar or paper township-well-spot maps and well cards. To research an oil-and-gas well, one first had to determine the well-permit number using the appropriate township well-spot map and then locate the corresponding well card by searching Geologic Records Center files by county, civil township, original land subdivision, and permit number. Computerizing the information has enabled rapid acquisition and analysis of large amounts of well data and the ability to perform multiple well-analysis tasks in a fraction of the time required prior to conversion.

Prior to the initiation of this project, a consistent system of coordinates had not been used for locating oil-and-gas wells in the state. Between 1860 and 1997, approximately 266,801 wells had been drilled in the state (Ohio Division of Oil and Gas, 1998). The quality of the location information for each of the wells varies from well to well. Some wells had very accurate coordinate location information in the form of footage calls surveyed from the original land subdivisions. A large number of those wells with footage calls had the state plane coordinates listed. The state plane coordinates of the wells were measured from the paper U.S. Geological Survey (USGS) 1:24,000-scale topographic maps. For large portions of the state, however, no reliable coordinate data are available for wells located on the township well-spot maps. For example, in northwestern Ohio, an estimated 76,000 wells were drilled prior to the 1930's (Wickstrom and others, 1992), before permits and location maps were required by the state to locate a well. Of the 20,000 wells in northwestern Ohio located on our maps as part of this conversion project, very few had coordinate information. Thus, this project has assigned consistent coordinate information to those wells. As another example, at the outset of this project, the former Division of Oil and Gas had a computerized database of wells permitted since 1981. Querying the database showed that of the approximately 100,000 wells in the system, only 60,000 had surveyor's footage calls. Another query showed that only 45,000 of the 100,000 well records contained state plane coordinates. As a result of the well-digitization project, there is now a consistent set of coordinates for all wells spot-

ted on ODGS's township well-spot maps. Additional research will be required to locate wells for which we have completion records in our files but incomplete location information.

Successful digitization of the state's oil and gas wells first required development of an accurate base map in order for well locations to be represented correctly relative to land subdivisions and other features on the base map. Wells must be accurately located on a base map in order to ensure that state spacing requirements are met. Many wells on the well-spot maps are located using the surveyor's footage calls measured from land-subdivision boundaries. Preliminary testing of the accuracy of digital well locations indicated that the project correctly transferred each well's spacing relative to surrounding wells. The new digital base-map files should nicely serve the needs of the oil-and-gas industry in Ohio for the location and management of well information. The base maps developed for the project also will be useful to many other agencies and constituent groups for other GIS applications.

Anyone using the ODGS hand-drafted township well-spot maps probably noticed a large variety of permit-number types identifying the wells. As the Division and the industry moved into the computer age, it became necessary to give unique identifiers to all the oil-and-gas wells to allow proper indexing within relational databases. The most widely used standard for assigning unique well identifiers is that of the American Petroleum Institute (API). The API coding scheme is the standard for reporting all wells in North America (American Petroleum Institute, 1979). Permit numbers issued by the former Division of Oil and Gas are API compliant. Unfortunately, the Division of Oil and Gas wasn't established until 1965. Wells drilled prior to 1965 were either not given permit numbers, were given permit numbers by the Division of Mines in the Ohio Department of Industrial Relations, or were given project numbers by either the ODGS or the USGS. In many cases, these well numbers are not unique. As part of the conversion process, ODGS assigned unique API numbers to all of the locatable wells in Ohio. These wells can now be indexed properly in the database. However, the original permit number that identifies a well on a map will be maintained because this number ties the well-spot location on the map back to the Geologic Records Center well card. These original permit numbers also will be stored in the new database system to provide a cross-reference to earlier work. Understanding the origin of the permit number associated with each well assists ODGS in its task of assigning unique API numbers to each oil-and-gas well.

HISTORY OF THE TOWNSHIP WELL-SPOT MAPS

To allow proper conversion into a GIS, it is important to understand the history of the township well-spot maps, specifically the data sources, the completeness of well information used, and the different types of well-identification numbers on the maps. The evolution of the regulations governing oil- and gas-well operations in Ohio has had much to do with the history of this map series. Prior to this project, however, a published history of Ohio's oil- and gas-well spot maps did not exist. The only published information or

²In 2000, the Ohio Department of Natural Resources merged the Division of Oil and Gas with the Division of Mines and Reclamation to form the Division of Mineral Resources Management. This project was completed before the merger, so the oil and gas regulatory agency is referred to as the Division of Oil and Gas, but the current regulatory agency is the Division of Mineral Resources Management.

comments on the township well-spot maps are in Shearrow (1959) and in Shearrow's memorial (Brannock, 1988).

Information on the spot maps comes from at least four sources: the former Ohio Division of Mines, the former Division of Oil and Gas, the ODGS, and the USGS. It is possible, that ongoing research will reveal other sources of information for well locations.

It was of particular interest for this project to know when surveyed well locations on plat maps were first required to be filed with the state and when and how permit numbers were first issued in Ohio. Three summaries of regulations concerning oil-and-gas operations have been found during this investigation: Wilson (1951), DeBrosse (1994), and a 1979 internal memo from the staff attorneys of the former Division of Oil and Gas (Appendix A). Unfortunately, there are conflicts among these summaries concerning certain regulations. For example, there are serious conflicts about when plat maps were first required for the location of a well.

The locations of wells on the original paper/mylar spot maps are primarily derived from plat maps that are submitted as one of the requirements for a permit application for drilling an oil-and-gas well. Plat maps for oil-and-gas wells were first required by the state in 1898 to protect coal-mining operations (Ohio Division of Oil and Gas 1979 memo; see Appendix A). A plat map was required to be submitted to the Chief of the former Ohio Division of Mines for every oil-or-gas well drilled in a coal-bearing township. This requirement was expanded significantly in 1951 to require a plat map to be filed for every well drilled anywhere in the state (Ohio Division of Oil and Gas 1979 memo). Thus, from 1898 to 1951, plat maps were submitted only for wells in the coal-bearing townships of eastern and southeastern Ohio. This requirement left out significant drilling activity in northwestern, central, and north-central Ohio (fig. 3). Because surveyed well locations in these areas were not filed with the state, spot-map locations for these wells had to be gathered from other sources. Thus, the locations for many of these wells are of questionable accuracy; many cannot be located better than placing them in the proper land subdivision, and some must be considered unlocatable at this time.

There are several different types of well-identification numbers on the well-spot maps. The majority of the numbers were issued by the former Ohio Division of Mines³, which had regulatory control over oil- and gas-well operations between 1898 and 1965, and the former Division of Oil and Gas after its creation in 1965. Of the other well-identification numbers found on the well-spot maps, the most numerous come from a study done by the USGS on the Bedford Shale and Berea Sandstone in the Appalachian Basin (Pepper and others, 1954). Other types of well-identification numbers are the "D", "L", and "H" numbers assigned by the ODGS. These numbering schemes were created by the ODGS for projects conducted between 1920 and the early 1960's. The USGS and ODGS projects form the bulk of the well-identification numbers assigned by nonregulatory agencies.

In 1936, the Ohio Division of Mines assigned identification numbers to all wells in coal-bearing townships drilled prior to 1936. These numbers were not unique; all the wells drilled within a given lease were issued the same number, followed by "-A" at the end of the number (fig. 4A). Permit numbers for new oil-and-gas wells were first issued by the former Ohio Division of Mines in 1936; these numbers were almost unique. Permits were issued per application rather than per lease. A permit application with one well was issued a unique permit number. If an application had two or more wells in it, then the permit number applied to all wells. To differentiate individual wells, a well number was added to the end of the permit number (fig. 4B).

In 1965, the Division of Oil and Gas was created in the Ohio Department of Natural Resources for the specific purpose of regulating oil-and-gas wells in the state, and began issuing unique permit numbers sequentially by county following API recommendations (fig. 5). The Division of Oil and Gas started the number series with the last permit number issued by the Division of Mines in each county. It also began to issue new "A"-series permits for old wells that were discovered in their regulatory investigations and for storage wells drilled during 1960-1963 and 1966-1967 (J. H. Glass, Division of Mineral Resources Management, personal commun., 1997). The new "A"-series permit numbers were issued for only one well, unlike the older "A"-series permit numbers assigned by lease (for wells drilled before 1936) or by application (for wells drilled between 1936 and 1965).

The USGS located wells as part of an effort by the federal government to discover strategic petroleum resources needed to assist U.S. participation in World War II. James A. Pepper was placed in charge of the program to study petroleum-bearing strata in the Appalachian Basin. The first major study looked at the Bedford Shale and Berea Sandstone (Pepper and others, 1954). For this study, drillers' logs were collected from various sources (largely well operators and landowners), and the corresponding well locations were plotted on a map and assigned numbers. The USGS geologists plotted the locations of the wells onto USGS 15-minute topographic maps. In Ohio, the majority of the well locations came from township well-spot maps provided by the Ohio Fuel Gas Company (predecessor to Columbia Natural Resources) and from surveyors' plats on file at the Ohio Division of Mines. The USGS needed a method to identify well locations and well logs, so a well identifier was created using a state code, a 15-minute topographic quadrangle code, and a 5-minute quadrangle subcode. The unique state code for Ohio is 00. Figure 6 shows all the 15-minute quadrangles used in this USGS study for Ohio. Each 15-minute quadrangle was assigned a unique number. Each quadrangle was subdivided into nine 5-minute rectangles by latitude and longitude, and each rectangle was assigned a number. The wells were assigned numbers sequentially within each 5-minute rectangle as USGS personnel plotted the locations (fig. 7; Appendix B). ODGS refers to these 15-minute topographic maps with the well locations as "Pepper maps" and the well identifiers as "Pepper numbers." The ODGS has copies of all such maps for Ohio.

By legislative mandate, the ODGS is the permanent archive for data pertaining to the geology of the state. As

³The Department of Industrial Relations was disbanded in 1995 and most of the functions of the Division of Mines were transferred to the Ohio Department of Natural Resources, Division of Reclamation, which was renamed the Division of Mines and Reclamation.

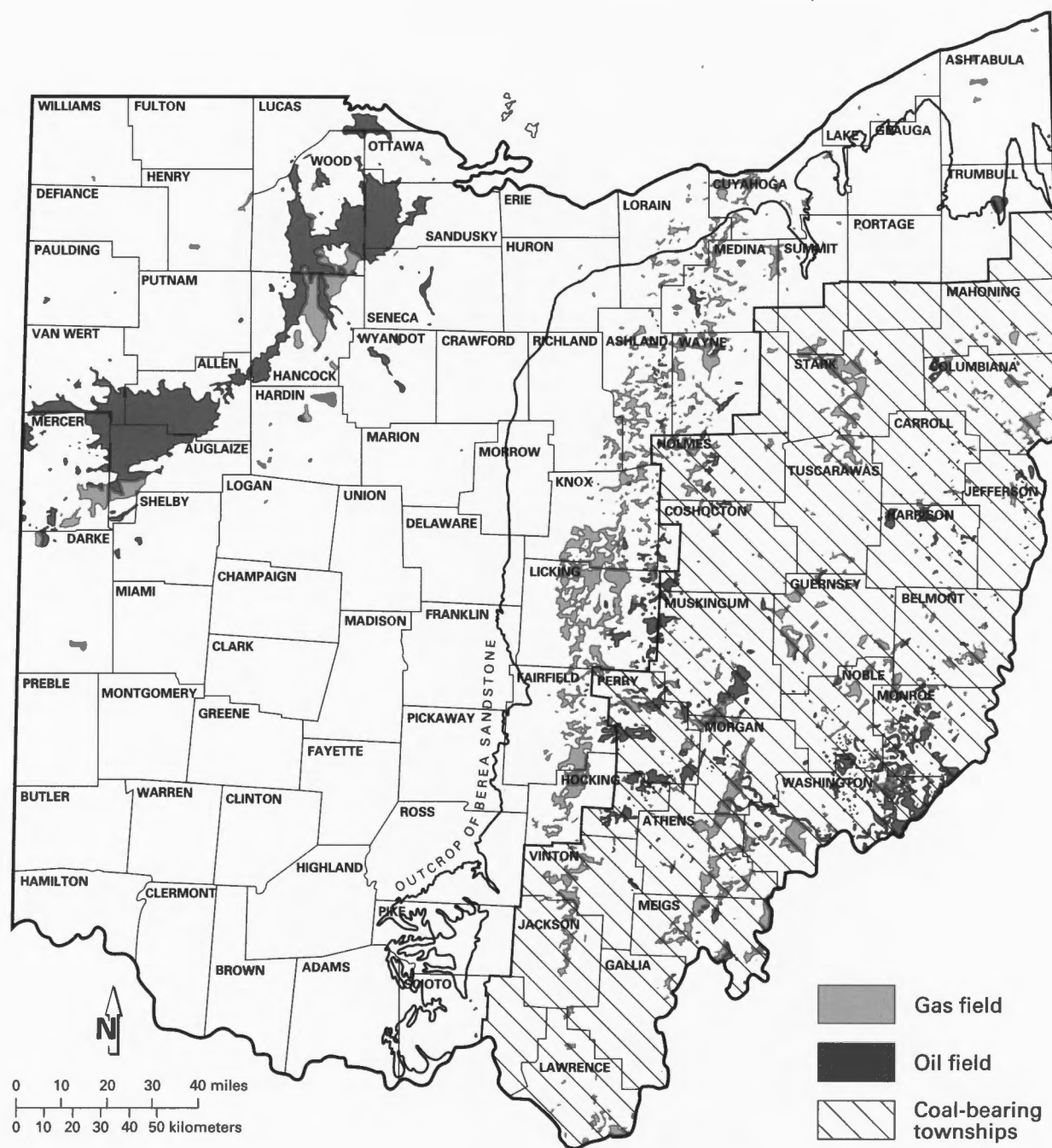


FIGURE 3.—Areal extent of the coal-bearing townships and extent of oil and gas fields as mapped in 1953 (Alkire, 1953). Wells drilled prior to 1951 that were outside the defined coal-bearing townships were not required to submit locations to the state. Therefore, the location information for these wells tends to be poor.

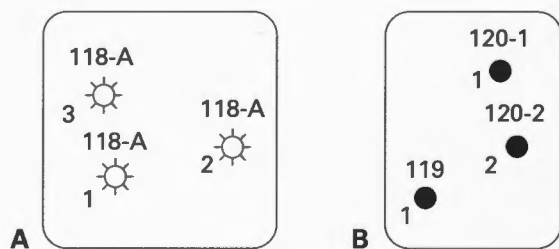


FIGURE 4.—Examples of nonunique numbering schemes. **A**, Pre-1936 scheme: All wells on a lease were given the same number followed by “-A.” **B**, 1936-1965 scheme: All wells on an individual application were issued the same permit number followed by a well number.

Modified American Petroleum Institute (API) 12-digit well-identification system:

1-2-3-4-5-6-7-8-9-10-11-12

where:

1-2 = State identification code, Ohio = 34

State codes 01-89 are reserved by API for identifying states, offshore areas, Mexico, and Canadian provinces.
Numbers 90-99 are reserved for internal use by companies.

3-5 = API county, parish, or offshore area code, alphabetical; in Ohio, Adams Co. = 001, Wyandot Co. = 175.

6-10 = Unique well code/permit number identification

Within the 5-digit unique well-code portion of the identifier, API reserved sequences as follows:

00001-20000 = Historical wells

20001-60000 = Current wells

60001-95000 = Reserved for "information important" well codes

95001-99999 = Reserved for proprietary use in company systems—not to be assigned by regulatory agencies.

11-12 = Sidetrack number

In order that sidetracks can be related to the original hole, yet be uniquely identified, a two-digit number (assigned serially) is placed in these spaces. These two digits are zero filled on the original hole.

Example:

API number = 341332739900

This number represents an Ohio (34) well drilled in Portage County (133) with the permit number of 27399. The information in this record is from the original hole (00), not a sidetrack.

FIGURE 5.—American Petroleum Institute basic 12-digit well-identification scheme. See American Petroleum Institute (1979) for a complete explanation of the well-identification system, classifications, state and county codes, etc.

such, it has collected oil- and gas-well information since its inception. The "D," "L," and "H" well-identification numbers shown on ODGS maps and records were used for specific ODGS projects conducted between 1920 and the early 1960's. The "H" well-identification numbers were assigned to Columbiana County wells located in preparation of Survey Bulletin 28 on the Geology of Columbiana County (Stout and Lamborn, 1924). ODGS employee R. E. Hutchinson had collected these well locations. Hutchinson's field notebooks and well-location maps are still in the Survey files. A query of the Survey's well-location database shows that the highest "H" number is 1,736, which matches the number of wells drilled in the county up to 1924 (Stout and Lamborn, 1924). The "L" well-identification numbers were assigned to wells in Lake County. The "D" well-identification numbers were assigned to deep wells throughout the state. Further research is required on these and other project-identification numbers that have been assigned to wells.

The current township-base oil-and-gas well-spot maps were created by the ODGS between late 1957 and 1961 under a team led by Theodore E. (Ted) DeBrosse and initiated by the head of the Subsurface Geology Section of the Survey at the time, George Shearrow. The basic work plan for the project involved gathering county engineer tax maps from each of the counties that had reproducible tax maps. These maps were developed by county engineers for use by county auditors. Once the ODGS obtained the tax maps

for a county, the oil- and gas-well plat maps from the Ohio Division of Mines were collected and their well locations and attributes were transferred to the tax maps. The land ownership information on the plat maps was an aid in the transfer of the oil- and gas-well locations to the tax maps (T. E. DeBrosse, personal commun., 1997).

Completion cards are an important part of the ODGS oil- and gas-well data sets and have an even longer history. In the late 1940's, Robert L. Alkire, first head of the Subsurface Geology Section of the ODGS, began a program to accelerate the recording of the well-log information. An ODGS employee was hired to work at the USGS New Philadelphia office to type the information from the USGS well logs onto 5 x 8 inch cards. These cards formed the nucleus of the ODGS well-card collection (T. E. DeBrosse, personal commun., 1997; Wallace de Witt Jr., personal commun., 1997; Appendix B). Other well cards were created from well information located in the literature. By 1950, the ODGS had in its files over 25,000 well cards (Melvin, 1951). When the well-location project was begun in 1957, Ted DeBrosse and the other geologists transferred oil- and gas-well information from the Ohio Division of Mines permits to the well cards and also onto the well-location maps (T. E. DeBrosse, personal commun., 1997). There are many instances where multiple well-identification numbers appear on a single well card; such cards are very useful for understanding the various well-identification-numbering schemes that have been used in the past.

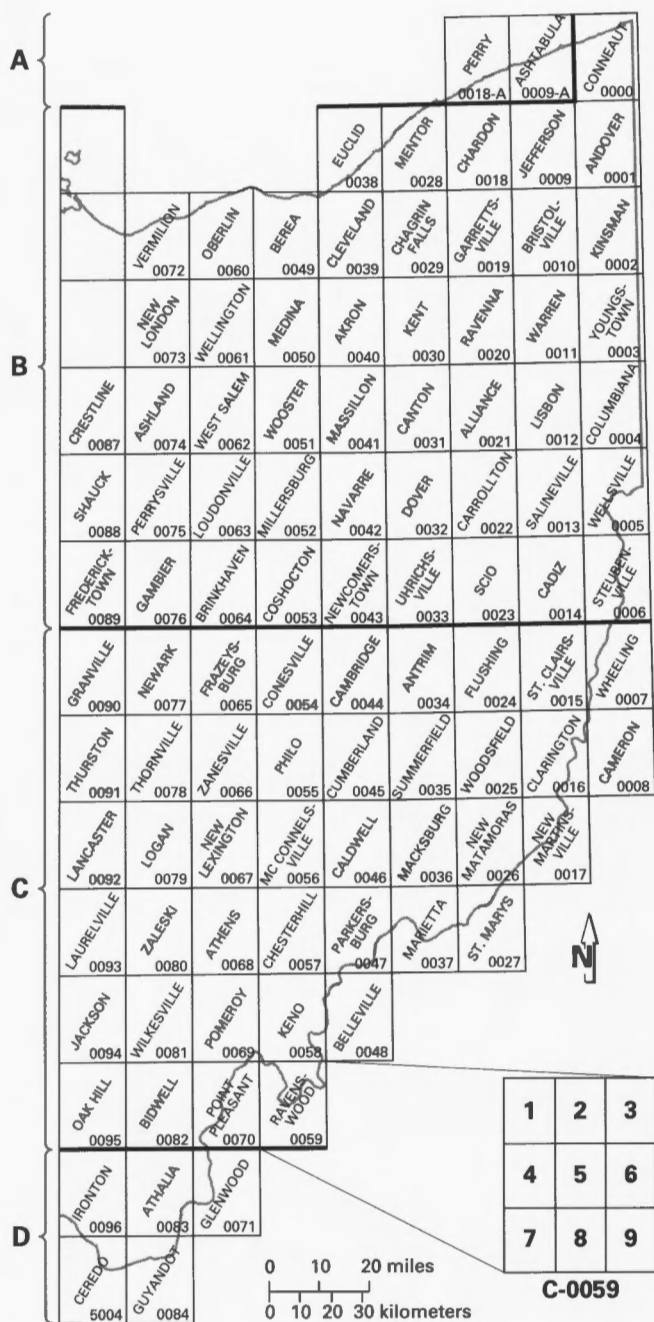
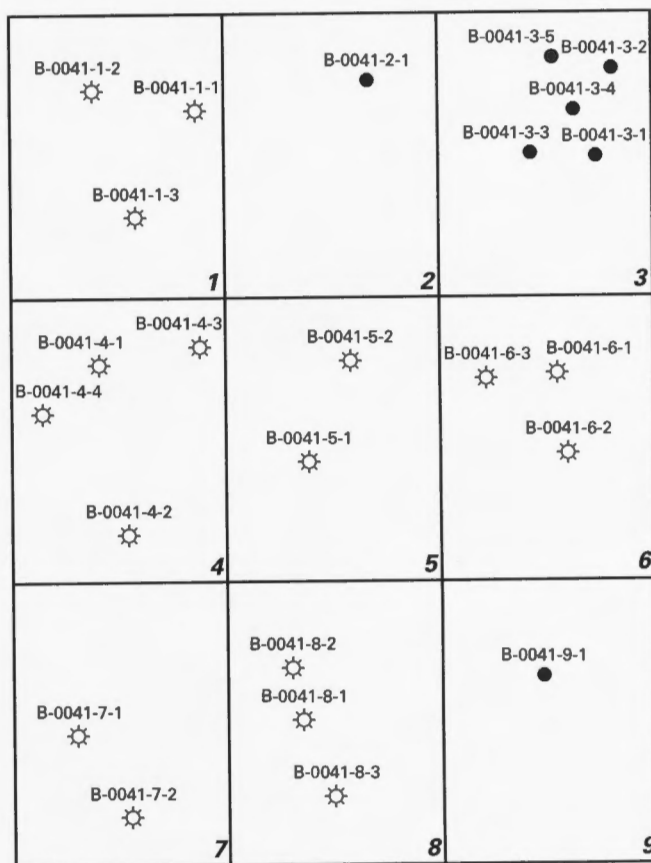


FIGURE 6.—Index map showing the location, name, and number of all the 15-minute USGS quadrangles on which Pepper and other USGS workers located wells in Ohio. The prefix letters **A**, **B**, **C**, and **D** were used to group the 15-minute USGS quadrangles in Ohio.

The county engineer tax maps that were assembled for plotting well locations were generally at the scale of 1:15,840, although some of the maps were at larger scales. For example, the Mahoning County tax maps were at a larger scale, each covering an area of one quarter-township. These quarter-township maps were photographically reduced and compiled to create a single 1:15,840-scale township map. Unfortunately, some of the original quarter-township maps



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FIGURE 7.—Example of the subdivision of a Pepper 15-minute quadrangle (Massillon) and how wells were sequentially numbered within each 5-minute subquadrangle.

were not all the same scale, were inaccurately drawn, or were miscompiled, as some of the assembled township maps have overlaps and gaps along the quarter-township boundaries. Other large-scale tax maps, such as the 1:9,600-scale maps of the Virginia Military District lands in Ross County, could not be assembled into township maps at 1:15,840 scale. The variable scales of some of the tax maps made the process of transferring the well information difficult.

When the Division of Oil and Gas was formed in 1965, ODGS provided photographic reproductions of the Survey's township spot maps to the new division. These maps became the standard base upon which the Division of Oil and Gas spotted wells. For many years, both divisions hand-spotted the same wells on their respective copies of the same maps, the Division of Oil and Gas for regulatory purposes and the ODGS for archival purposes and release to the public. This duplication inevitably led to differences in the two map copies. As part of the current computerization project, the differences between the maps were resolved and both divisions are now using the same digital maps.

The old township well-spot maps were created at a scale of 1:15,840, which is more commonly known by the verbal scale of 1 inch to 1,320 feet or 4 inches to a mile. There are

many problems in using these maps as a base for spotting well locations. The land-ownership information on the maps is out of date by 30 to 50 years or more, and keeping this information current is well beyond the means of either the ODGS or the Division of Oil and Gas and its successor, the Division of Mineral Resources Management. Some photographically compiled maps have edge-matching errors. Many of the maps are greatly out of scale in both the x- and y-axis from years of being pulled through various copy machines.

Perhaps the main problem with the old township well-spot maps is that many of them do not have the land subdivisions drafted correctly. The tax maps are not legal documents and are not required by law to be accurate. They were assembled by the county engineer to serve as an index to parcel ownership only and are not the legal means by which parcel ownership is represented and conveyed. Figures 8-10 illustrate some examples of inaccurate township tax maps. On many of the maps it appears that the drafters idealized the land subdivisions. In figure 8, the drafters drew orthogonal, 1-mile square sections, when in reality the section is not a square mile in area nor are the corners at 90° angles. In figure 9, the Cuyahoga River, which forms an original land subdivision boundary, has been idealized. Figure 10 shows an inaccurately drawn Lake Erie shoreline. Some wells in shoreline counties have been located relative to the Lake Erie shoreline. Using the Lake Erie shoreline as a survey control presents a particular challenge, as the land-water

interface changes as a result of lake-level fluctuations and erosion of the shore face. For the digitization phase of this project, rectifying the inaccuracies of the township maps was one of the biggest challenges.

BUILDING A DIGITAL BASE MAP

To produce an accurate product in this digitization effort, it was necessary to register the original paper and mylar township well-spot maps to an accurate representation of the land subdivisions for Ohio; this registration process is known as "rubber-sheeting." Using a process called "digitizer setup," the computer operator registers a number of points (minimum of four) on the original map (which is taped down on a digitizing table) to corresponding points on the digital map. The computer program then stretches and squeezes the input to minimize error over that area. The setup program reports error statistics that allow the operator to judge how accurate the representation will be. ODGS data standards require that wells spotted on a base map must be depicted within 100 feet of their actual location. Some of the original township maps were so distorted that a digitizer setup had to be run on each section/subdivision in the township.

The success of this project largely depended on the accuracy of the digital base map that was used. There have been a number of previous efforts to build a digital base map for Ohio. The Ohio Department of Transportation

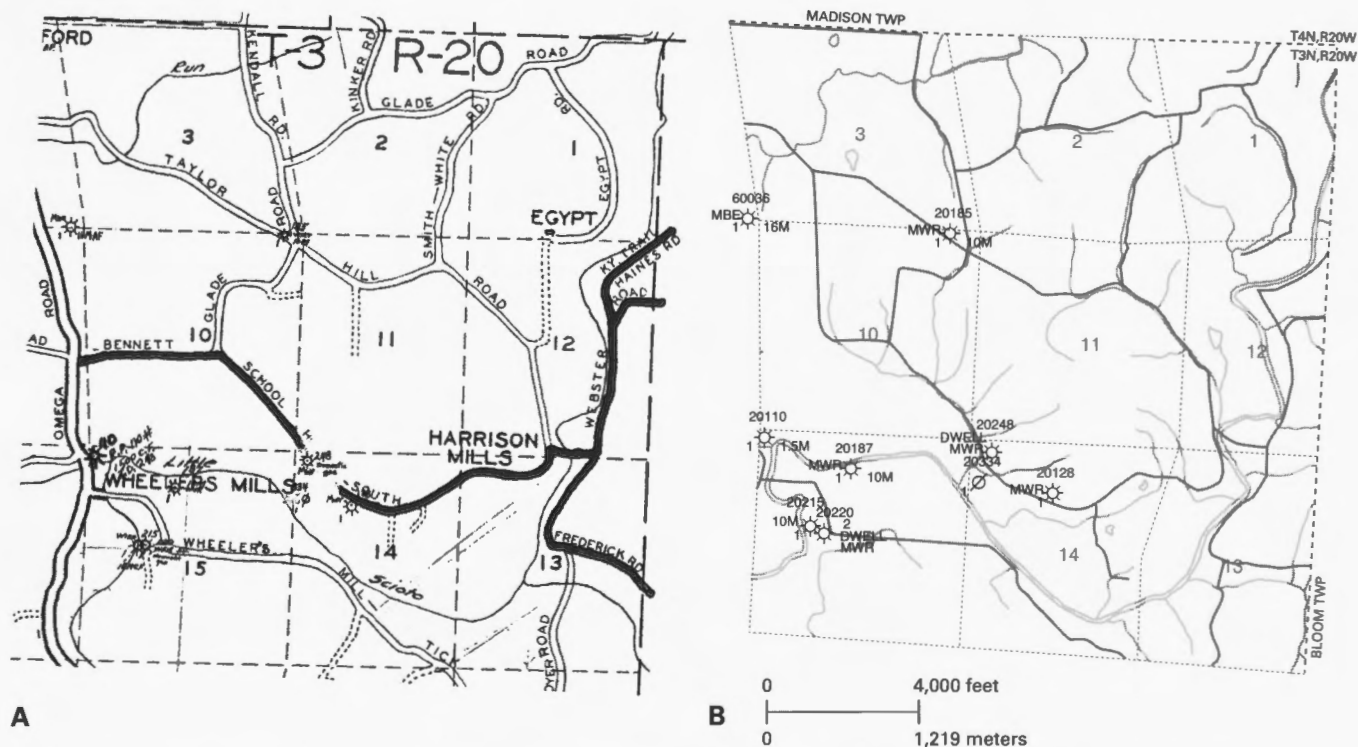
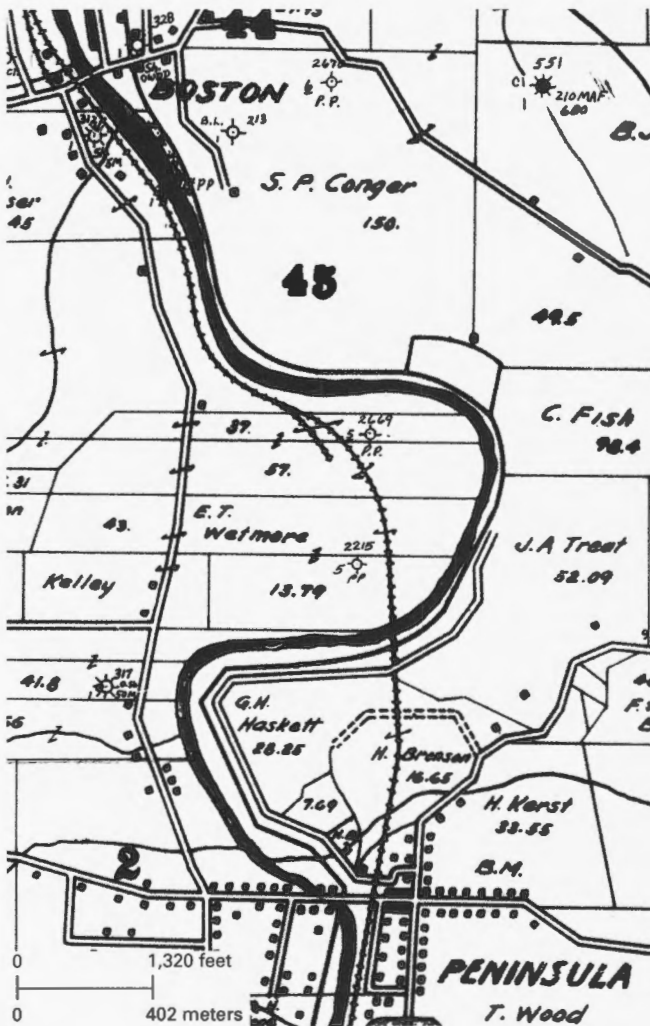


FIGURE 8.—Comparison of a portion of Harrison Township, Scioto County, showing the land subdivisions as depicted on the old township well-spot map (A) and the same land subdivisions on the new digital base map (B) compiled from USGS 7.5-minute quadrangle DLG's. Note the different shapes and sizes of some of the subdivisions. Note particularly how the eastern boundary line of section 14 jogs to the northeast in B but is straight on figure A. There is more than 300 feet of misclosure between the two maps at the northeast corner of section 14. See figure 16 for the well-symbol explanation.



A



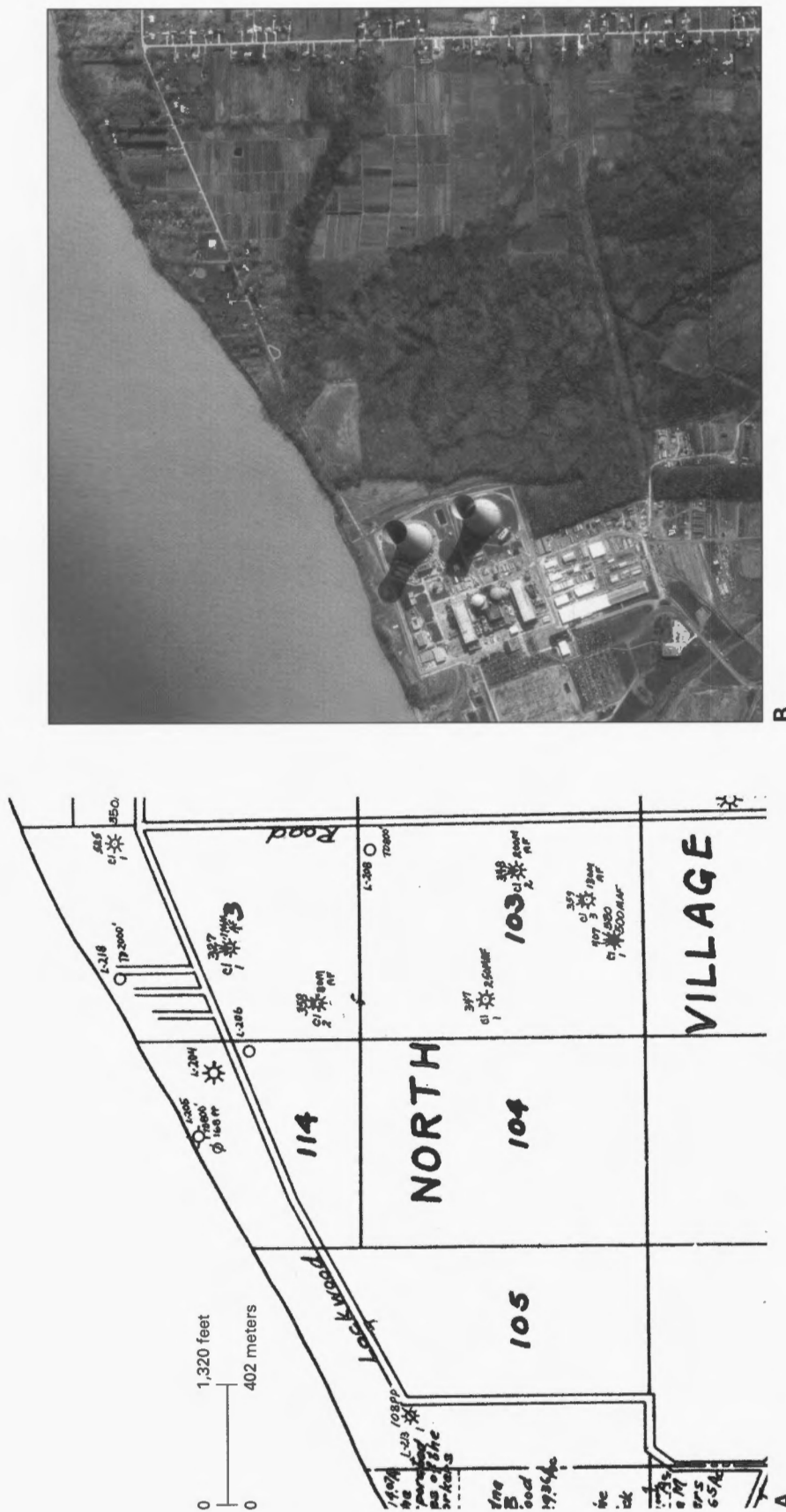
B

FIGURE 9.—Comparison of the Cuyahoga River in Boston Township, Summit County, as depicted on the old township well-spot map (A), and the same area as depicted on the USGS digital orthophoto map (B). The river is an original land-subdivision boundary line, and there is more than 1,000 feet of misclosure between the aerial image and the map. Rivers meander over time, but 1,000 feet of misclosure is excessive. Although exact the date of the tax map for Boston Township is not known, it was obtained from the Summit County Engineer between 1957 and 1960. The USGS topographic maps for this area were first constructed from orthorectified aerial photography in 1949 (Northfield 7.5-minute quadrangle) and in 1951-1952 (Peninsula 7.5-minute quadrangle). The USGS updated the topographic maps in 1994 using aerial photography and the Cuyahoga River had not changed its relative position between the time of the original maps in 1949 and 1951-1952 and 1994. Therefore, the tax map has inaccurately portrayed the river, and hence the original land-subdivision boundary lines.

(ODOT) initiated the first effort about 1980. Between 1980 and 1985, ODOT digitized the following elements from the USGS 1:24,000-scale topographic maps: 7.5-minute quadrangle boundaries; political boundaries such as state, county, township, and municipal boundaries; Public Land Survey System (PLSS) boundaries (sections); roads and railroads; airport locations; and hydrography (streams and lakes). ODOT digitized the maps using Intergraph's IGDS software, whose native file format is DGN (design file). Another effort to build a contiguous statewide base map was initiated by the Public Utilities Commission of Ohio (PUCO) in the late 1980's. PUCO's files did not include the PLSS section lines, which were of critical importance to the ODGS project.

Other small-scale digital base maps that became publicly available by the mid 1990's include the U.S. Bureau of the Census TIGER (Topologically Integrated Geographic Encoding and Reference) files and the USGS 1:100,000-scale DLG (Digital Line Graph) files. Both the TIGER files and the DLG files were considered to be too inaccurate for spotting the locations of oil and gas wells. Furthermore, the TIGER files did not include the PLSS section lines, and the DLG files did not cover the entire state.

By 2000, some county auditors were building what are perhaps the most accurate digital base maps for political boundaries and original land subdivisions of the state. These GIS data layers are at scales ranging from 1:1,200 to 1:



4,800, using the American Society for Photogrammetry and Remote Sensing Accuracy Standards for Large-Scale Maps (American Society for Photogrammetry and Remote Sensing Specifications and Standards Committee, 1990); use of these standards translates into an accuracy of 1 to 4 feet RMSE (root mean square error). County auditors are building GIS' to help modernize their tax maps. Unfortunately, although the county auditors are using internal standards for building their GIS, they are not using statewide standards. As a result, there is no consistency among the GIS' of the various county auditors. The meaning and structure of the same GIS data layer may be different from county to county—one county might build the original-land-subdivision layer in the GIS from the original records, but another county might not include the original land subdivisions, only the parcel boundaries. For example, Franklin County has built its GIS base map researching the original land subdivisions, but neighboring Delaware County decided, at the time of the initiation of this project, to not include the Virginia Military District subdivisions (but by 2003, Delaware County had captured the Virginia Military District subdivisions). These data-definition and data-structure problems make it difficult to merge the different county auditors' digital base maps. The second problem with using county auditors' GIS data sets for this project is that fewer than five of the 88 county auditors had completed construction of a GIS by the time the ODGS had initiated this project in 1996. Current (2003) practices of the county auditors to convert the tax maps to a GIS do not capture everything consistently across the state. In addition, not all counties can afford to create a GIS at this time.

The ODGS had been using ODOT's digital base maps since 1987 for smaller scale mapping projects and, therefore, was familiar with their structure. When the well-spot-map project began, it was thought that these files would be sufficient for development of fundamental, reliable base maps. After capturing well locations and attributes for the western half of the state, it was discovered that the ODOT base map had a number of problems. First, although ODOT did perform quality control on the layers that were of importance to its mapping applications, the PLSS lines were not a priority and so were not given rigorous quality-control evaluation. Initial comparison of the PLSS lines between the paper 1:24,000-scale topographic maps and the digital files showed location errors ranging up to 500 feet. ODGS had hoped to use ODOT's section lines and digitize only the irregular subdivisions in the state, but such wide-ranging errors were unacceptable because the PLSS layer was one of the most critical features needed for our project. The second major problem with the ODOT files was the Ohio state plane coordinate system zone boundary. By law, the Ohio state plane coordinate system zone boundary falls along a specified set of county lines (Ohio Revised Code, 1985, Chapter 157). When ODOT digitized the counties and quadrangles that fall along the zone boundary, they introduced a distortion so that neighboring counties in different zones could be merged seamlessly together without a coordinate transformation. This distortion ranges anywhere from 0 to 200 feet horizontally for those boundary counties, depending upon distance from the principal meridian. This distortion affected

elements within those county files, rendering them useless for ODGS needs.

ODGS decided to use ODOT base maps for areas in northwestern and southwestern Ohio (see fig. 11) that did not have problems with the Ohio coordinate system, for a number of reasons. First, the well locations and attributes had already been digitized. Second, the majority of the wells in northwestern Ohio were drilled prior to 1920, so the locations were not very accurate to begin with; northwestern Ohio also has the best use of regular sections in Ohio and the least amount of topographic relief. Thus, the ODOT base maps for northwestern Ohio were found to be within accuracy standards. Third, there has been very little drilling in southwestern Ohio, and locations of most of the wells that have been drilled were measured from the township boundaries because of the lack of regular sections.

Fortunately for this project, several Ohio state agencies, including ODNR, were involved in a cooperative agreement with the USGS to convert all the USGS 1:24,000-scale topographic maps to DLG files. The resultant DLG files are very accurate digital representations of the elements of the 7.5-minute quadrangles. The contractor for that project was The Ohio State University's Center for Mapping, and the project was known as Generating Information from Scanning Ohio Maps (GISOM) (Center for Mapping, 1996; Ramirez, 1996). The DLG files represent the most accurate and consistent set of contiguous digital base maps available across the State of Ohio.

Using the new DLG files was considered to be the best solution for a number of reasons. First, these data conform to the National Map Accuracy Standards (U.S. Bureau of the Budget, 1947) for 1:24,000 scale. According to the standards, maps published at 1:20,000 scale and smaller will have no more than 10 percent of the points tested to be in error by 1/50 inch or greater, or, more simply, an accuracy of ± 40 feet. This standard meets the Division's accuracy needs of ± 50 feet. Second, there is continuous coverage of DLG data for the entire state and there is consistency in the types of features that are contained within the DLG files. Third, the original 7.5-minute quadrangle maps are based on orthorectified aerial photography. These maps represent true spatial representations that can be observed from the adjusted aerial photographs. As previously shown (see figs. 8-10), the hand-drafted tax maps do not show real spatial representations.

An additional reason for using the USGS DLG maps is that they include the hypsography (elevation contours). No other map series in the United States has as detailed hypsography as this map series. The final, and most compelling, reason to use the DLG files is the accuracy of the PLSS features. Although the USGS does not claim legal responsibility for the accuracy of the PLSS data, it was discovered that considerable effort was made to recover the PLSS section corners for Ohio. According to the specifications used to create the topographic maps (U.S. Geological Survey, 1980), all efforts must be made to recover the PLSS section corners so that the PLSS lines can be represented accurately. Examination of the original source materials stored at the USGS offices in Rolla, Missouri, revealed that the surveyors collected, in the field, the locations of the original section corners. The surveyors used copies of the original survey plats from 1786

to 1820 to survey and recover the section corners. These plat copies came from the National Archives in Washington, D.C. This effort to accurately recover and represent the section corners gave the Division confidence that this map series would meet the needs of the oil and gas industry to locate wells throughout the state.

Unfortunately, the GISOM project was not completed by the time the Division needed the base map for this project. The ODGS had to digitize some of the political boundaries and PLSS section lines from the 1:24,000-scale paper topographic maps. Quality-control checks of the digitized political boundaries and PLSS lines indicate that the work is within National Map Accuracy Standards. However, for consistency, the Division plans to replace the quadrangle-derived files as DLG files become available. Replacing digitized data with the DLG data will not degrade the accuracy of the digitized well locations, as the digitized data conform to National Map Accuracy Standards. Figure 11 shows the quadrangles that used the DLG files and the quadrangles that the ODGS digitized in house.

To complete the original-land-subdivision layer, the quadrangle-derived section lines were supplemented by adding the original, irregular land subdivisions. Ohio was the first state in which the federal government subdivided the land before it was sold. This process started in 1785, immediately following the Revolutionary War. Between 1786 and 1838, many different schemes were used to subdivide the land. In Ohio, nine major schemes were used, along with many different minor subdivisions (Peters; 1918, Sherman, 1925) (fig. 12). Eventually, the federal government settled upon the PLSS. This township-range-section system was first applied in the United States in northwestern Ohio. The PLSS layer in the USGS DLG files does not include the irregular land subdivisions of Ohio, which occur in the following surveying districts: Virginia Military District, Ohio Company Purchase, Donation Tract, Connecticut Western Reserve, and U.S. Military District. Numerous other small surveys, such as the French Grants, Refugee Grants, and the Twelve-Mile-Square Tract contain irregular subdivisions. These subdivisions are well described in Sherman (1925).

Many well locations were surveyed from the boundary of irregular land subdivisions, so the irregular land subdivisions had to be included in the PLSS layer of the DLG files in order to accurately digitize well locations. However, finding a consistent, accurate set of base maps from which these irregular subdivisions boundaries could be digitized proved to be fruitless. The county engineer tax maps were the starting point, but in some cases, the lines were not reliable or could not be read from the tax maps. In those cases, alternative sources for the irregular land subdivisions were used. These sources included Ohio Fuel Gas township well-spot maps, ODGS county base maps, county plat books, Pure Oil Company township well-spot maps, Sherman's (1925) figures, Sherman's (1922) map (used as a secondary source for Virginia Military District lots), and Quaker State Oil Company base maps (used especially as a tertiary source for the Virginia Military District lots).

To digitize the irregular land-subdivision lines, digitizer setup was performed on a township tax map to the digital base map assembled from the DLG files. If the misclosure

between the township map and the digital base map was greater than 50 feet, then a digitizer setup was performed on a smaller area of the tax map. If the setup statistics showed that the average error was greater than 0.25 percent or that the maximum error was greater than 0.40 percent, then a digitizer setup was performed on a still smaller area of the tax map. It was discovered that the digitizer setup routine was dependent on the size of the area—smaller areas had smaller misclosures between the digitizer-mounted tax map and the digital base map. Once an acceptable digitizer setup was accomplished, the operator digitized the irregular land-subdivision lines into a graphics file. The new information (lines and labels) for the subdivisions was placed on eight different levels within the CAD (computer-aided drafting) files for ease of manipulation. Four levels contained the new subdivision lines, while four other levels contained the text for the new subdivisions. It was determined that beyond the PLSS township-and-range subdivisions, there are no more than three levels of subdivisions within the irregular land subdivisions (fig. 13A), irregular subdivisions below the township level were grouped into three different levels for the graphics and three different levels for the text attributes. The two larger subdivisions are termed large and intermediate irregular subdivisions (figs. 13B and 13C). These subdivisions were placed on the two highest levels. The smallest subdivision is the lot (fig. 13D). All lots are found on the same level in all base map files. In the Connecticut Western Reserve, a number of townships and ranges or quarter-townships were divided into square-mile subdivisions. These are the equivalent of PLSS sections, so the subdivision lines and text were separated onto their own levels, which correspond to the seventh and eighth levels.

The resultant digital base-map series contains county, township, section, and irregular subdivision lines captured either from DLG files or by digitization. The digital ODOT files have been rectified to allow ODOT hydrography and transportation layers to be shown on the new base maps.

WELL-DATA CAPTURE PROCESS

The Ohio Department of Natural Resources contracted with the Ohio Department of Rehabilitation and Corrections Ohio Penal Industries (OPI) to capture the oil- and gas-well locations and attributes. OPI supplied inmate labor from within the Ohio prison system (Wickstrom and others, 1998); OPI subcontracted with Lockwood, Jones, and Beals, Inc. (LJB) to provide project management, oversight, inmate training, and software programming. The ODGS provided the original well-location maps (mylar, linen, or paper), paper copies of the well-location maps, digitization and data-entry technical specifications, the digital base-map files, and final quality control of the submitted product. This division of labor worked quite well and enabled the successful completion of the project.

In April 1996, prior to initiation of the project, LJB met with the ODGS staff members to develop a plan and schedule of work. LJB started with a county-level pilot project; Noble County was selected as the pilot county. Data-capture and data-entry guidelines were provided to the contractor and a schedule was established, including delivery dates and



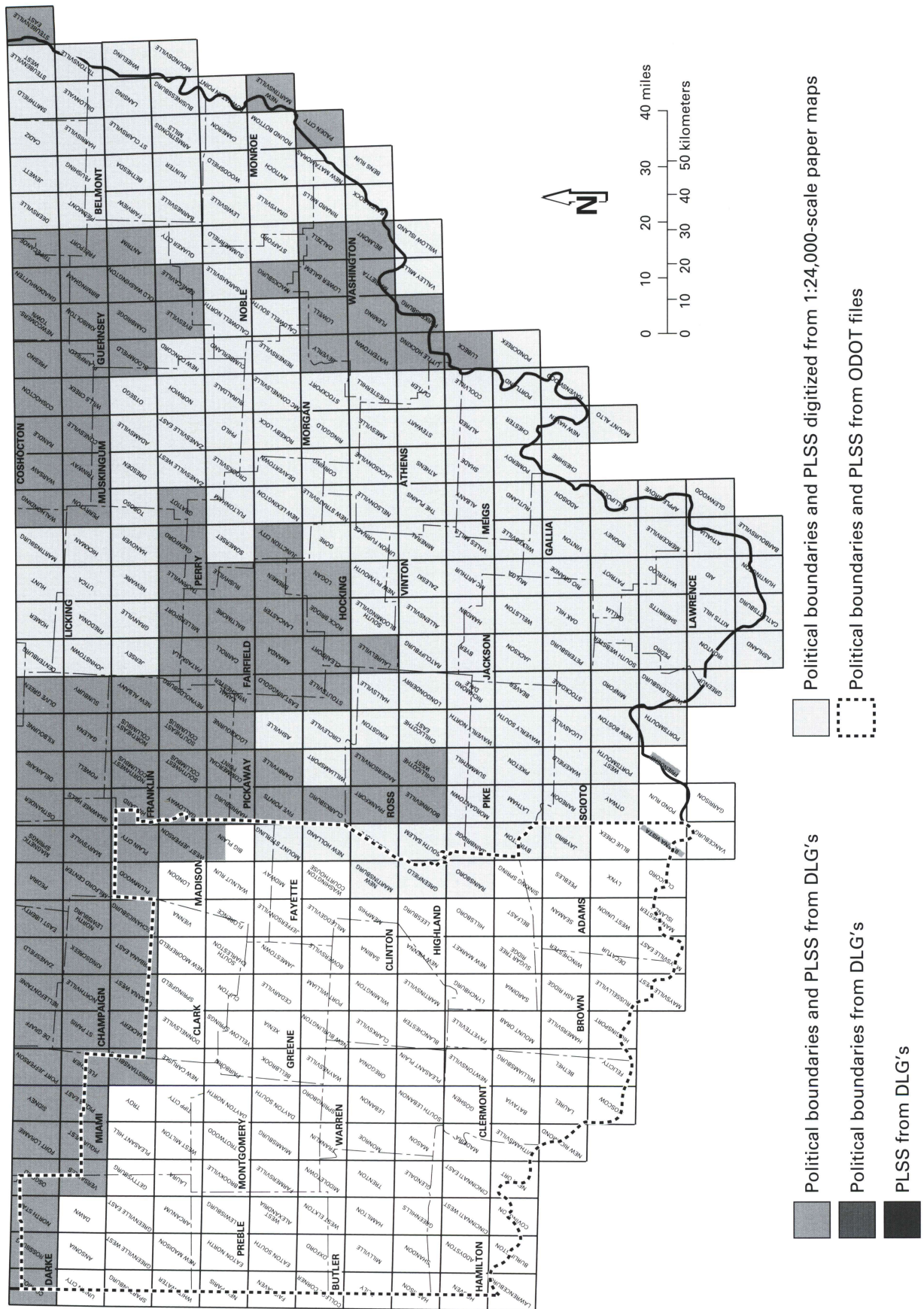


FIGURE 11.—Index map showing the sources of information, by quadrangle, for the new digital base maps of Ohio.



FIGURE 12.—Index map showing the original land subdivisions of Ohio.

return dates for all source maps and products. The state was divided into nine groups of counties (fig. 14); one area was to be completed before moving on to the next. Work began in western Ohio, where there is very little current drilling activity, and then moved into eastern Ohio. This plan allowed the inmates to become familiar with the process and to increase turn-around rates before working on counties having the greatest current oil and gas activity. Once the contract work had begun, the ODGS constructed digital base maps for use by the contractor ahead of the project-area due dates. Using the digitizer setup procedure described above, the contractor digitized the well locations into a digital file. The contractor, subcontractor, and the ODGS then performed quality-control measures to ensure that the well locations and information were correctly transferred to the digital file.

Software development

Software had to be developed prior to the project implementation to help automate data capture, data editing, and database creation and maintenance. The new software was created in two different CAD macro languages. The first program, ODNRT.MA, was the macro used by the operator to place the well symbol and the associated attributes within the well graphics file. This software contained a menu of well symbols for the operator to use when digitizing the well locations. The menu contained the 35 well symbols found on the Survey's spot maps (see fig. C-2), plus a special symbol to indicate unknown well status. The second program, WELMOD13.BA, was used to edit the well symbol and the attributes surrounding the well symbol. The final program

supplied, EXPDB.MA, loaded the information contained in the graphics files into a relational database.

A digitizing procedures manual (Appendix C) was compiled to standardize the OPI digitizing workflow and helped eliminate inconsistencies among digital-input operators. The operator first gathered the copies of the original township well-spot maps. Two blank graphics files, well file (.WEL) and the background file (.BGD), were created for each township to contain the well locations and the base-map information. The operator then copied the relevant information from the digital county-base-map file into the blank township-base-map file (.BGD). The township base map file was then cleaned up to eliminate all graphics outside the township boundaries and the title block was placed inside the township graphics file. A digitizer setup was then performed on the original township well-spot map. If the misclosure was greater than 50 feet, the operator performed a digitizer setup on a smaller area. The operator checked the reported errors for the digitizer setup. If the digitizer setup average error was greater than 0.3 percent or the maximum error was greater than 0.8 percent, the operator filled out a Digitizer Setup Tolerance Form to indicate the digitizer setup could not be adequately performed. Once the digitizer setup was acceptable, the operator selected the appropriate well symbol from the ODNRT.MA dialog box and digitized the well location from the original map. The program ODNRT.MA placed the appropriate well symbol (see fig. C-2) at the digitized location. The operator added the attributes surrounding the well symbol on the township well-spot map. These attributes include the permit number, the lease number, the first producing formation, the second producing formation, initial production of oil, initial production of gas, and the permit type code. The operator logged any problems encountered, such as an unreadable or unknown permit number. In the latter case, the operator used a sequential log number in the place of the permit number to identify the well and entered the log number onto a discrepancy log sheet. The discrepancy log sheet gave the ODGS a sense of what problems were encountered by the operators and what solutions the operators attempted during the course of the project. After all wells in a township were digitized, a plot of the graphics file was prepared at the same scale (1:15,840) as the original township well-spot map. Some townships that were too large to be plotted at this scale were plotted at 1:24,000 scale.

One of the most critical components of this project was to conduct quality-control tests to check whether the well-spot maps were converted accurately. These quality-control checks were performed by overlaying the original well-spot maps on the new plots of the digital well-spot maps. Quality-control checks were performed at least three times on each township map prior to its acceptance. An OPI operator performed quality-control checks on the finished graphics file. If any problems were found, the corrections were done at the OPI facility. The graphics files for an area were then submitted to LJB, which performed a second quality-control check. Finally, the graphics files, along with the original source materials, were delivered to the ODGS. At the ODGS, college interns performed quality-control checks on all the township maps returned by the contractor. If the interns found a map that had a high percentage of unacceptable well locations and attri-

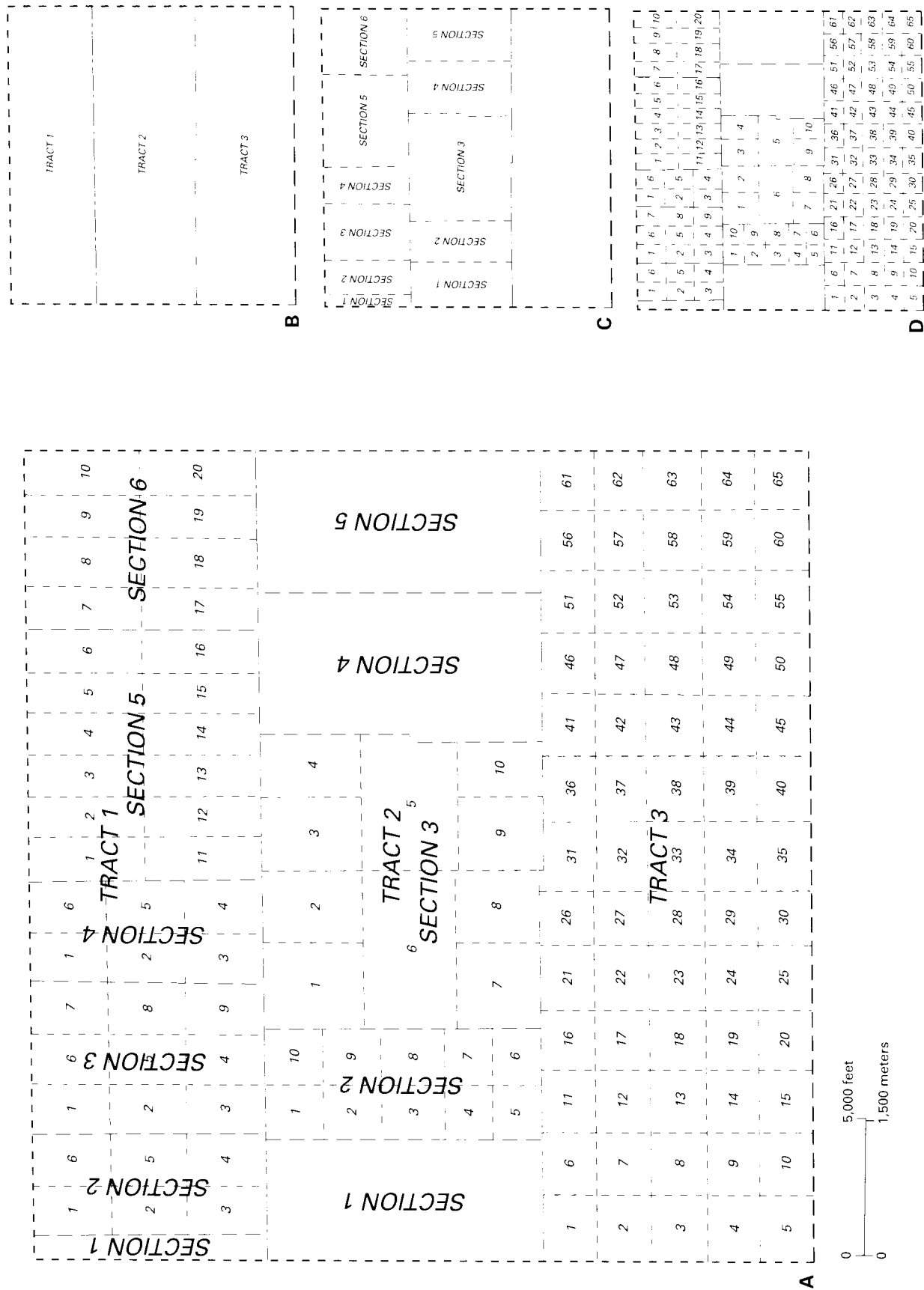


FIGURE 13.—Original land subdivisions (**A**) of Township 6 N, Range 8 W, Connecticut Western Reserve. This original land-subdivision township corresponds to the civil township of Auburn Township, Geauga County. The three levels of subdivisions in this township are tracts (**B**), a larger level of irregular subdivision in Ohio; sections (**C**), an intermediate level of irregular subdivision in Ohio; and lots (**D**), the smallest irregular subdivision found in Ohio. Intermediate and larger subdivisions also may be called tracts, allotments, sections, subdivisions, sections, divisions, ranges, subranges, and named lots. The “section” in example C should not be confused with a PLSS section.

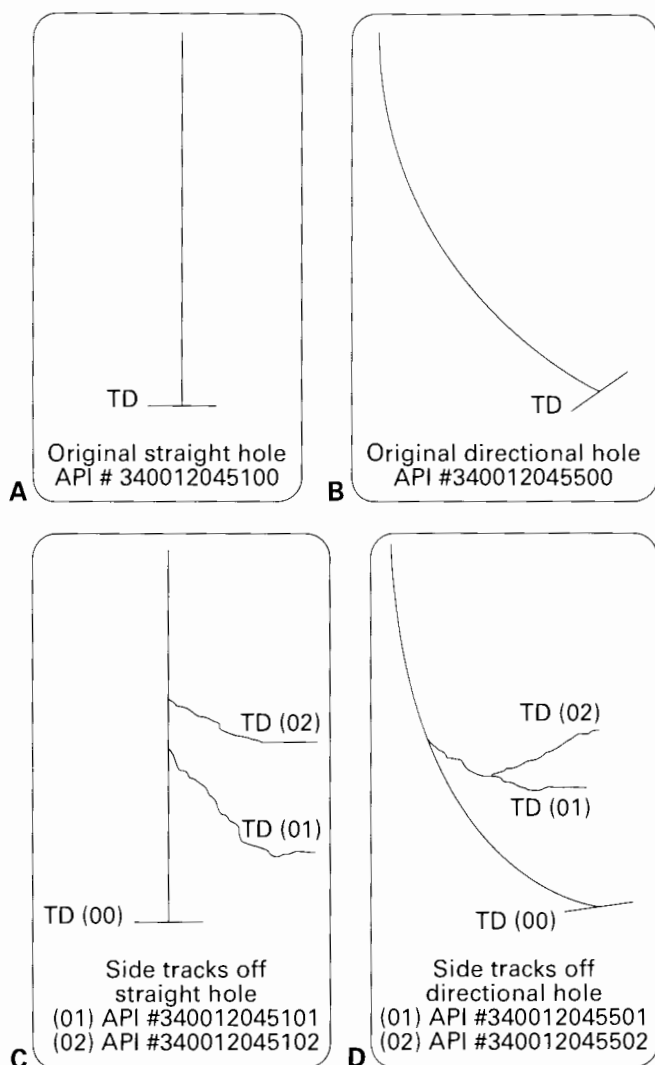


FIGURE 15.—Illustration of use of the 11th and 12th digits of the API numbering scheme for directional wells. When a well is drilled, either as a vertical drill hole or as a directional drill hole, the well bore is assigned an API number, whose 11th and 12th digits are zero (0). For example, the vertical drill hole has an API number of 340012045100 (A). The directionally drilled hole has an API number of 340012045500 (B). If there are additional completions off to the side of the original well, then these bottom-hole locations are given new API numbers using the 11th and 12th digits. For example, for the original vertical drill hole (A), two additional bottom-hole completions were drilled and were assigned API numbers of 340012045101 and 340012045102 (C). For directionally drilled well (B), the API numbers for the new bottom-hole locations are 340012045501 and 340012045502 (D).

be changed on the well-spot maps and added to the paper well record. The staffs of the ODGS and the Division of Oil and Gas, several college interns, and OPI inmates performed this large undertaking.

The "R" permit-type codes assigned by the Division of Oil and Gas since 1965 are already API compliant. Although all "R" permit numbers were understood to be in the 20000 series ("current wells" category in the API scheme; see fig.

5), the Division of Oil and Gas and ODGS had not used the full 20000-series number for filing or map labeling prior to this project. For example, a well assigned an API number 340592355900 had always been referred to, filed by, and mapped as permit number 3559 of Guernsey County. All four-digit "R" permit numbers had to be converted to five-digit numbers. Using the previous example, the permit number on the map, in the attached data file, and on the paper record had to be changed from 3559 to 23559. Adding the appropriate state (34) and county (059) numbers gives the complete API number.

Because of the way in which historical wells had been handled in Ohio, it was difficult to adhere strictly to the API definition for historical wells—using 00001-20000 in the well-code/permit-number portion of the API number. The Division of Oil and Gas had been using a "0" (zero) as the first digit of the well-code/permit-number portion of the API identifier (as is proper by API definition) to identify historical wells it had discovered and entered into its file system (referred to as the 0-series). The Division of Oil and Gas most commonly acted upon these old wells when a plugging permit was filed or an old well was identified during a field investigation. Most such instances involved old "A" numbered wells. The Division of Oil and Gas staff simply put the "A" number as the permit number, preceded by a 0. This practice led to some duplicate record numbers because of the nonunique nature of these early permitting schemes.

Additionally, all the "A" numbers identified by the Division of Oil and Gas had not been entered into the computer database; they were kept on hand-written lists, some of which were missing. The task of assigning new identifiers to historical wells would be much simpler, programmatically, if all non-"R" permit-type codes could be sequentially numbered without having to worry about which ones had already been assigned a 0-series number.

This combination of factors led the Divisions to use the 60000-series for numbering the historical wells. Using 60000-series identifiers for historical wells eliminated the concern with duplicating numbers already in use in internal or external databases. All non-"R" permit types were sequentially numbered, and the 0-series wells already assigned were matched up to their new 60000-series number after processing and the 0-series record deleted from the data system.

Because the old permit-number systems have been in use for so long, these numbers are ingrained into publications and company and regulatory files. Thus, a tie to the old permit numbers had to be maintained. Two old-permit-number fields were added to the RBDMS. The old "A" numbers, Pepper numbers, etc. were placed in these fields for cross-referencing. This cross reference allows someone who only knows an old well by the original permit number to find it in the new database system with its new 60000-series identifier.

In March 1998, the Ohio Department of Natural Resources contracted with OPI to reassign new permit numbers to all wells contained on the township well-spot maps following these guidelines:

1. Add 20000 to all permit number with the "R" type code (new/regular permits).

2. Sequentially number all non-"R" type codes starting with 60001 in each county.
3. Retain old map permit numbers in alternate-permit-number fields; the old numbers would not to be displayed on maps.
4. Post all new five-digit permit numbers back to the spot maps.
5. Adjust graphics for any overlap caused by longer permit numbers.
6. Merge the background CAD files containing roads and streams with oil- and gas-well location files.
7. Update the well symbols in the files.
8. Perform quality assurance/quality control procedures on resultant maps and files.

Using the database generated by digitizing Ohio's oil- and gas-well locations and the associated CAD well-location maps, OPI generated a new identification number for each well on the maps. For non-"R" type permit codes, the new API numbers were assigned sequentially by county, starting with number 60001. For example, the full API number for the first "A" number in Licking County is 340896000100. The new number and the old number are stored in an associated data file.

In the winter of 1998, staff from ODGS and the Division of Oil and Gas met to update the well-symbol list (fig. 16). New symbols were added and some symbols were removed from the list. The new well-symbol list better reflects the functional status of the oil and gas wells and the new list was added to the editing software prior to the initiation of the next phase of the project. During the project to update the well-location maps, the maps were searched for wells that needed to be updated with new well symbols and appropriate modifications were made to those wells.

As each county was completed by the contractor and returned, ODGS staff and interns matched each township map against the previous version of the map to check for completeness and errors. Each well was matched with its paper record (well card) and a special colored sticker with the new five-digit identifier number was applied to the well card. Wells for which no paper records were found were marked appropriately in the database. Appendix E lists the steps used in checking these maps and records. This process provided another round of edit checks to the returned maps and records as well as a permanent link between the digital maps/data and the paper records.

Once the verification and file-labeling work was completed, the new map-derived, file-verified database was merged with the existing RBDMS database. This merger provided all existing RBDMS wells a consistent set of map coordinates and added over 100,000 new records to the RBDMS system. The new records contain only map attributes, but will enable anyone using the system to create their own set of maps and have a more complete listing of wells in any given area. The contracted work was completed in late 1999 and all verification and labeling was completed in summer 2000.

An added benefit of this phase of the project was having OPI merge the roads and streams onto the digital base maps used for the township well-spot maps. ODGS interns then placed additional geographic references such as surrounding

township names and township and range indicators to the new township spot maps. These additional geographic features and references make it much easier for users to locate the wells in reference to known landmarks or features.

SUMMARY AND RESULTS

The Ohio oil- and gas well-digitizing project has accomplished much toward the computerization of the oil and gas records for the state. The project has created 1,355 digital township well-location maps and has transferred approximately 217,000 well locations from the original maps to the new digital base maps. Each oil and gas well now has a unique API-compliant well identifier. The project also has resulted in a consistent and more accurate base map. Future wells can now be located consistently and accurately. The new digital well-spot maps allow for better archiving of information. There are instances of mylar or paper township well-location maps being lost over time. It took a considerable amount of time to recreate the township well-spot maps by hand using the well cards. By having the maps in digital form, they can be stored almost anywhere and be recreated at any time, and Ohio government agencies and the public can now take advantage of the more usable digital data.

An unexpected benefit of this project was the history of the oil- and gas-well records at the ODGS and the Division of Oil and Gas. Although the history of the township well-location maps had never been fully compiled, this history was needed to understand the completeness of the oil- and gas-well records and the completeness of the maps. The history also imparted an understanding of the older well-identification numbering systems, so that new API numbers could be properly assigned to all wells. This report represents an effort to document the history of the original compilation of the township well-spot maps and their digital conversion. Because of the difficulty encountered in discovering the history of the original township well-location maps, the ODGS will fully document all future GIS conversion projects it undertakes so that researchers and the public can understand the methodology, accuracy, and completeness of the conversions.

A number of items remain to be addressed in regard to the township well-location GIS. The base maps that were constructed for this project are a hybrid of USGS 1:24,000-scale DLG and ODOT data. The hydrology data from ODOT need to be replaced with more accurate data from the DLG's. The transportation layer needs to be updated with current ODOT data. The township and municipal political boundaries do not reflect annexations that have occurred since the period of 1957-1960 and need to be updated using data from the county engineers'/county auditors' GIS. The new base maps do not have the land-ownership information that the original maps had. However, land-ownership information is difficult to maintain on a statewide basis; the individual county auditors can best maintain this information. As of January 2003, approximately 55 counties in the state had either begun or completed creating a GIS for property-tax information, with 20 counties having fully operational systems (S.R. Davis, Ohio Department of Administrative Services,









































 Permitted location	 Well producing gas with a show of oil from multiple horizons
 Expired permit location	 Well producing gas from multiple horizons
 Gas show	 Well producing oil from multiple horizons
 Gas well	 Plugged well that produced oil with a gas show from multiple horizons
 Plugged gas well	 Plugged well that produced oil from multiple horizons
 Gas and oil show	 Well producing oil with a gas show from multiple horizons
 Oil show	 Plugged well that produced gas with an oil show from multiple horizons
 Oil well	 Plugged well that produced oil and gas from multiple horizons
 Plugged oil well	 Well originally drilled for oil and gas, but converted to a water well
 Gas well with oil show	 Brine well for dust and ice control
 Oil well with gas show	 Plugged brine well for dust and ice control
 Plugged oil well with gas show	 Water supply well
 Oil and gas well	 Plugged water supply well
 Plugged oil and gas well	 Lost hole
 Plugged gas well with oil show	 Radioactive geophysical tools lost in hole
 Dry hole	 Observation/monitor well
 Dry hole with gas show	 Unknown status
 Dry hole with oil show	
 Dry hole with oil and gas show	
 Injection well	
 Plugged injection well	
 Well producing oil and gas from multiple horizons	
 Plugged well that produced gas from multiple horizons	

FIGURE 16.—Wells symbols shown on the township well-spot maps and are currently used by ODGS and the Division of Mineral Resources Management.

GIS Service Bureau, personal commun., 2003). Most of these systems are being created at very high resolution scales, such as 1:4,800 or larger. These new types of digital base maps are of greater accuracy than the base maps derived from the USGS 1:24,000-scale topographic maps. As time and technology proceed, users should be able to combine the ODGS map files with the county auditor file of their choice. Finally, the oil- and gas-well data need to be converted into proper GIS software format. Currently, the oil- and gas-well data reside in database tables, which can be easily placed into a GIS. But the effort that went into placing the well attributes, so that they could be readable, would be lost in the process. The locations of the well attributes need to be preserved during the conversion into proper GIS format. As of January 2003, all of these issues were either in the process of being implemented or in the planning stages.

The conversion of the well-spot maps to digital form allows for many different enhancements. The maps and the database will be dynamic. In the future, as wells are permitted or completion reports are turned in, the informa-

tion will be automatically posted onto the maps, eliminating delays between issuance of the permits and posting of the information onto the maps. Another enhancement is that the information can be merged into the Ohio Department of Natural Resources enterprise database RBDMS. All of ODGS tabular information that we have concerning oil and gas in the state will be stored in RBDMS or linked to it. These databases will form the core information within the oil- and gas-well GIS. The GIS, when implemented, will automate certain functions that currently take a long time to complete. Two such applications involve creating areas of review for injection wells and updating of the Ohio oil- and gas-fields maps. In regard to review of injection wells, there would be no lag between the time the well application is submitted and when the area of review is initially analyzed. The Ohio oil- and gas-fields maps would be updated continuously from the database.

The new digital well-spot maps are the beginning of an integrated GIS for the ODGS. The well-data files and graphics files from this project are all freely available to

the public via the ODGS World Wide Web site at <<http://www.ohiodnr.com/geosurvey/>> or on CD-ROM.

ACKNOWLEDGMENTS

This project was funded in large part by the State of Ohio through *NatureWorks* (The Ohio Parks and Natural Resources Bond Fund). We thank David Crecelius, Ohio Department of Natural Resources, Office of Information Technology, for his support and contractual guidance with this project. We also thank our student interns Theresa Baiamonte, John Bramlet, Eric Farber, Judy Roth, and Karen Shufeldt for their help in assembling the digital base-map files, digitizing the irregular subdivisions, performing the quality-control checking, and editing the final versions of the digital township well-spot maps. Student interns Eric Farber, Steven Flandro, and Karen Shufeldt performed additional quality-control work on the digital well-location maps and database. Student interns Eric Domyan, Eric Farber, Steven Flandro, Donovan Powers, and Corey Todd labeled the well cards with the new API numbers. Inmates at the Marion and Orient Correctional Institutions are to be commended for a job well done in capturing the well locations and assigning the new API numbers. We also thank David Lewis and Douglas Kotnik of LJB, Inc., for their efforts to ensure that the project maintained a high standard of quality. As always, we extend our warm appreciation to our editor, Merrienne Hackathorn, and electronic design coordinator, Lisa Van Doren, for making us look better than we deserve.

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**APPENDIX A.—Historical Overview of Oil & Gas Well Permitting in Ohio,
internal memo, Ohio Division of Oil and Gas, December 14, 1979**

This memo has been retyped verbatim; annotations are in brackets.

December 14, 1979

HISTORICAL OVERVIEW OF OIL & GAS PERMITTING IN OHIO

The historical emphasis concerning the development of Oil and Gas Law, and hence a permitting system in Ohio, has been on mine safety. Below, is a list of the State requirements for the submission of a drilling application and plat prior to the establishment of the Division of Oil and Gas.

- 1883 – 80 O.L. [Ohio Law] The first law was passed requiring casing for the protection of fresh water aquifers.
- 1898 – 93 O.L. “An act to protect the Mines in Ohio” was passed requiring a map to be filed with the Chief Inspector of Mines showing the location of all wells on any coal bearing land.
- 1917 – 107 O.L. Mining laws were enacted requiring a map and application to be filed with the Division of Mines before the well was drilled in coal bearing townships.
- 1927 – 112 O.L. Laws were amended as to provide Oil and Gas Well Inspectors to enforce the laws relating to the drilling and plugging of well[s] in coal bearing townships; required a drilling log to be filed with the Division of Mines for wells in coal bearing townships.
- 1933 – 115 O.L. The law was amended requiring a drilling log to be filed for any [oil and gas] well drilled within the State.
- 1936 – The Division of Mines established a numeric permit number system for each county[;]
A – numbers are assigned to existing wells.
- 1951 – 124 O.L. The law was expanded requiring an application and map for any [oil and gas] well drilled within the State.
- 1964 – In response to the “Boom” in Morrow County, the Division of Mines issues emergency rules requiring an application, bond, and [minimum] well spacing.
- 1965 – H. B. 234 The Division of Oil and Gas was established and required an application, map, bond, fee, drillers log, and inspections.

**APPENDIX B.—History of the U.S. Geological Survey office in
New Philadelphia and the origins of the “Pepper” maps and numbers**

This memo has been retyped verbatim; annotations are in brackets.

From: Wallace de Witt, Jr., USGS retired
To: Jim McDonald, Ohio Geological Survey
Subject: The Pepper well location numbers.

September 14, 1997
Memorandum

In 1943 as part of the United States Geological Survey's Fuels Section war effort to locate additional supplies of oil and gas within the United States, Geologist James Franklin Pepper was assigned by Section Chief Hugh D. Miser to make a study of petroliferous rocks in the Appalachian basin. Pepper, who had much experience working for the Belmont Quadrangle Drilling Company, Wellsville, NY in the Appalachian basin, realized that a regional well location system would be essential to his studies because of the many different and confusing well location systems used by academia, the states, and industry throughout the Appalachian basin. Given a relatively small crew of mainly neophyte geologists, Pepper set up an office in the basement of the Muskingum Watershed Conservancy District in New Philadelphia, Ohio and set his crew to gathering well data and plotting strip logs at the scale of 1" = 100' to make a stratigraphic and isopach study of the Berea and associated sandstones basin wide.

Jim Pepper knew from admonitions of John F. Carl that "A well log with out a location was useless." Consequent [ly], Pepper placed great emphasis on obtaining a location for each log shown on his data base. No log will appear without a location in our well log collection was his order. The location system established by Pepper used the USGS 15-minute quadrangle as the basic element because most of the basin excepting parts of eastern Kentucky was covered by the 15-minute topographic quadrangle map network. Each state was assigned a number and each quadrangle was given a unique number within the state. Pepper then subdivided the quadrangle into 9 5-minute rectangles by latitude and longitude coordinates. These 5-minute rectangles were numbered from 1 in the top left of the map, 3 in the top right, 5 in the center rectangle, 7 in the lower left and 9 in the lower right. The wells were assigned numbers serially within the individual rectangles as they were located in our office files. Thus, the first well in the first ninth rectangle, the top left, NW, of the first quadrangle in the New York state file would be 1-1-1. New York state unique number was 1 because Pepper donated his personal collection of well logs, which used the number 1 to identify the state, to the New Philadelphia effort. I believe Ohio's unique number was 1000 [Ohio's number is 00], so the first well located in the 9th, SE, 5-minute rectangle in Ohio's first 15-minute quadrangle would be identified by the number 1001-9-1 [actually 0001-9-1]. With this system operative, we were able to locate any well log in the system in a few minutes, and when plotted we could retrieve the strip log in less than 5 minutes.

Pepper's group collected well logs from many sources: the literature, archives, state geological surveys and such state agencies as the Division of Mines, large and small companies, individual consultants, well drillers, and from "sitting" on drilling wells.

Because wells were commonly located on farm-line property ownership maps, Pepper's group obtained a variety of farm-line maps from county engineers, plat map services, county auditors offices, and other sources. In Ohio the farm ownership maps were a mess. Some were platted at different scales from 1" = ¼ mile to 1" = 1 mile. Many were out of date by 30 or more years and some counties lacked any farm-line maps at all. We took the material that was available. Most were blueprints that were not scale stable.

Most fortunately for the Appalachian Basin Project, Jim Pepper was a great friend of Kenneth Cottingham, the Chief Geologist of the Ohio Fuel Gas Company, and with L. W. Frost, the man in charge of the Ohio Fuel's map department. The Ohio Fuel Gas Company, now part of the Columbia Gas System, had by far the most complete, accurate, and up to date set of farm-ownership maps in Ohio. I believe that sometime in the late 1950's or early 1960's the Ohio Fuel donated a set or sets of their maps to the Ohio Geological Survey. These maps formed the basis for the Ohio Survey's extensive well collection data base [Further research has shown that the Ohio Division of Geological Survey did not use the Ohio Fuel Gas maps as a source

of information for its well locations. The primary sources of information for the township-well-location maps were the Pepper wells and the Ohio Division of Mines permits. See the "History of the township maps" portion of this report for more information.) Pepper and his geologists were given complete freedom using the Ohio Fuel's farm-line maps with the proviso that they would not be published, although the data from them might be used in other investigations or published in part but not in toto.

We spent many hours checking locations at the Ohio Fuel's office at 99 Front Street [Columbus, Ohio]. Without Cottingham's and Frost's help, our job of collecting and identifying well locations would have been much more difficult. The Ohio Fuel's maps showed both company and foreign well locations by symbol and number which often aided in resolving problems of well numbers when two logs were found on a property, both logs being identified as the #1 well.

A very real problem was the lack of accurate elevations for most well logs in the area. Many wells had no assigned elevations. Some elevations were run in by barometer, some by level, and many we gestimated [sic]. Because the elevation control was so poor, we were unable to accompany our isopach maps with structure maps, a feature that Pepper was sure the industry would appreciate.

As the state surveys tightened regulations during the 1950's and 1960's, the more accurate well head elevations were required. The introduction of the 7.5-minute quadrangle with an abundance of good benchmarks led to companies being able to supply much more reliable elevations for their well locations.

At times during the 15 years that the New Philadelphia Fuels office was open, members of the Ohio Survey would come by to check well data and copy well logs and locations. I recall that Ray Lamborn spent some time in our office. Bob Alkire hired a young woman to copy data for him. She spent a number of months copying information in the New Philadelphia office. Others came by for short times and I have forgotten just who they were. Jack Melvin and Ralph Bernhagen called by to discuss mutual problems with Pepper and me often involving the collection of well cuttings, logs and well locations.

In 1953 Jim Pepper took over the job of regional geologist for all USGS fuels work, coal, oil, and gas east of the Mississippi River and I moved up to Project Chief of the Appalachian Basin Fuels Program with a reduced staff. We continued Pepper's program of collecting well data and keeping our files open to the public for examination and data copying.

When I was ordered by Branch Chief Jim Gilluly to shut down the office and transfer the contents to Washington in 1958, we had more than 53,000 located, plotted, and correlated logs in our data base for the Appalachians from New York to the southern borders of Virginia and Kentucky. Bob Ryder, USGS Reston, Va., has charge of the collection of well logs and location maps as well as a copy of the microfilmed record set.

In order to avoid loss of our well log collection by fire, flood, or other disaster, we micro-filmed the entire collection on 35 mm microfilm. We deposited the collection with the Library of Congress in Washington, D.C. When I was ordered to close the New Philadelphia office and move the collected material to the USGS headquarters in Washington, I sent a specific state area copy of the well-collection microfilm to each of the state geological surveys within the area of our studies in the Appalachian basin. I expect that this transfer of data accounts for the greater number of "Pepper Number" well logs and locations that are in the Ohio Survey's well data base. I also attempted to send all of the well cuttings in our files to the respective state surveys. I later learned that some of these cuttings went astray and were never received by the agency to which they were addressed. This I regret, but I was given orders in April of 1958 to have the New Philadelphia office closed down and all the equipment, records, and most personnel transferred to the Washington, D.C., office by July 1, 1958. This included selling homes as well as closing down the office. It was a hectic 3 months during which Murphy's law took full command.

I am sure that I have inadvertently omitted important data from this brief memorandum. However, I didn't keep a diary during those times and I'm looking back between 35 and 54 years ago. My memory isn't as sharp as it might be. Also we crowded a lot of subsurface and field work into those 15 years when the New Philadelphia office was functional. Those were exciting and stirring times when we operated with a minimum of red tape and advice from Washington. It was an enjoyable time.

APPENDIX C.—Ohio Penal Industries operators manual

During the course of the project to convert the township well-location spot maps, the OPI inmates developed a procedures manual to consistently convert the township well-location maps and also resolve discrepancies with the well symbols and attribute information on the spot maps. The initial sets of rules were established during the contract start-up meeting in April 1996. Additional rules were created during the course of the project as deviations from the initial set of rules were encountered. The following sets of rules were used to convert the township well-location maps during the course of the project, which ran from April 1996 to May 1997. This conversion was completed before the API well identifiers were assigned, so these rules apply to the original permit numbers.

The first set of rules applied to the appearance of well locations and attributes. These rules included final well-text arrangement, stacking of well text in areas of dense drilling and permitting, and leaders pointing from the stacked text to the well symbol. The software supplied to the operators automatically formatted the placement of the well symbol and the associated attributes (fig. C-1A). For directionally drilled wells, both slant and horizontal, the well attributes were placed at the bottom-hole location (fig. C-1B). The surface location was marked by only a circle and an "S," to indicate it is the surface location of a directionally drilled well. In areas of dense drilling, placing the well attributes required them to be stacked and move to a different location. The well attributes were tied to the well symbol by the use of a leader line (fig. C-1C). Not shown in the operators manual are the cartographic rules for the appearance of the final township plot, such as the title, as well as rules on the scale of plotting for the final product.

The next set of rules for capturing the well information dealt with the well symbols. The menu of 35 different well symbols (fig. C-2) had all the standard well symbols and some of the more common nonstandard well symbols. The common nonstandard well symbols were related to the standard symbols through the software. If there was uncertainty about the correct symbol to use, the operator used a special star symbol (★). During the course of the project, the contractors discovered more than 50 nonstandard well symbols on the well-spot maps. Interpreting the meaning of many nonstandard symbols was a challenge for the operators, who had to convert the nonstandard well symbols to standard symbols. As new nonstandard well symbols were encountered, an example of the symbol was shown to the staff geologists at ODGS. The ODGS staff made an interpretation as to the standard well symbol that should be displayed. To aid the operators, a table (fig. C-3) was created showing all the nonstandard well symbols and their conversions to the standard well symbols.

Figure C-4 illustrates specific examples of well-symbol rules concerning permitted and expired-permitted well symbols. In some cases, an "A" well identifier with a permitted well symbol (open circle) had a producing formation and an initial production. The symbol and the attributes indicated that the well was drilled, was productive, but its true productive status is currently unknown. The operator changed the

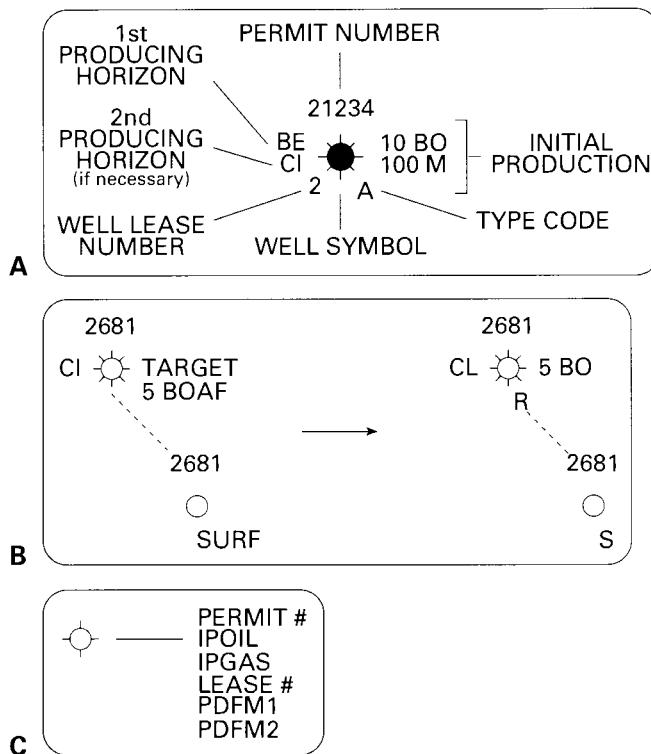


FIGURE C-1.—Illustration of the rules for placing well symbols and attributes (A), and the capture rules for directionally drilled wells (B), and stacking order for wells that require a line (leader) connecting the well symbol and the text (C). See Appendix C for a further explanation of the figure.

well symbol to the star symbol (fig. C-4A). An Orient Correctional Institute (OCI) or Marion Correctional Institute (MCI) numbered well that had a permitted well symbol indicated a well location that had no assigned permit number. Its current productive status is unknown, so the well location is assigned the star symbol (fig. C-4B). In many cases, there were additional text attributes surrounding a well, such as LOC (uncertain location), which the operator was to ignore (fig. C-4C). This information can still be obtained from the archived original maps and from the well cards. For an "A"-numbered well that had an expired permit well symbol (open circle with a slash) and the producing formation and initial production indicated, the well symbol did not change and the operator would transfer all the information except the producing formation (fig. C-4D).

Another set of rules governed the permit numbers (fig. C-5). As noted previously, a number of permitting schemes and projects have assigned numbers to individual wells. "A"-number permits did not uniquely identify the well. In order to identify a well uniquely with a number, the ODGS modified the well-permit number by adding the lease number to the end of the "A"-permit number (fig. C-5A). In figures C-5B-D, the "D," "L," and Pepper ("B-0000-") well-identification numbers were not modified. If a well had multiple well-identification numbers, only one of those numbers could





































	Permitted location		Injection well
	Expired permit location		Plugged injection well
	Gas show		Well producing oil and gas from multiple horizons
	Gas well		Plugged well that produced gas from multiple horizons
	Plugged gas well		Well producing gas with a show of oil from multiple horizons
	Gas and oil show		Well producing gas from multiple horizons
	Plugged gas and oil show		Well producing oil from multiple horizons
	Oil show		Plugged well that produced oil with a gas show from multiple horizons
	Oil well		Plugged well that produced oil from multiple horizons
	Plugged oil well		Well producing oil with a gas show from multiple horizons
	Gas well with oil show		Plugged well that produced gas with an oil show from multiple horizons
	Oil well with gas show		Plugged well that produced oil and gas from multiple horizons
	Plugged oil well with gas show		
	Oil and gas well		
	Plugged oil and gas well		
	Plugged gas well with oil show		
	Dry hole		Water originally drilled for oil and gas, but converted to a water well
	Dry hole with gas show		Plugged water well
	Dry hole with oil show		
	Dry hole with oil and gas show		Unknown status

FIGURE C-2.—Well symbols shown on township well-spot maps, which were provided to the digitizing operators as menu selections. See Appendix C for a further explanation of the figure and see figure 16 for the current well-symbol list.

be used for the graphics file. The rule for multiple permits was to first use regular permit numbers issued by the Division of Oil and Gas, then "A" permit numbers, "D" numbers, "L" numbers, "H" numbers, and lastly Pepper numbers. In figure C-5E, if the well-permit number was unreadable or if the well did not have an identification number, then the well is assigned an OCI or MCI well-identification number. In figure C-5F, if a well had a lease number with a letter "A", the "A" does not get appended to the permit number. Any extraneous text associated with the permit number, such as "PP" (permit to plug) in figure C-5G, was dropped.

The rules for encoding the initial production of oil and gas and the permit type were fairly straightforward. Figure C-6A shows the acceptable location for the initial production (IP) of oil and gas and the acceptable abbreviations for the initial production of oil and gas—BO for barrels of oil, M for thousand cubic feet of gas, and MM for million cubic feet of gas. In cases where if there was more than one IP value for either oil or gas (fig. C-6B), the operator dropped the initial production in parentheses and used the last reported production, in this case, 100 MAF (100 thousand cubic feet after fracture). The type of stimulation treatment, which in figure C-6B is After Fracture (AF), was also dropped. All fractions and dashes found in numbers were replaced with a decimal value (fig. C-6C).

The permit-type code rules were relatively easy to implement. Well-identification numbers without a letter were assumed to be regular permit numbers and the well was assigned an "R" type code (fig. C-6D). Well-identification numbers with an "A" in the permit number were assigned an "A" type code (fig. C-6E). Well-identification numbers that began with "A-0000-," "B-0000-," "C-0000-," "D-0000-," or a "-" were Pepper well-identification numbers and were given a "P" type code (fig. C-6F). Well-identification numbers that began with an "L" or a "D" were given "L" and "D" type codes (figs. C-6G and C-6H), and OCI or MCI and "H" well-identification numbers were given a "U" type code, to indicate unknown (fig. C-6I).

The lease-number rules also were straightforward. Any "A" well-identification number had its identification number appended with the lease number (fig. C-7A). The software programs used for data capture had a field length of only 5 characters for the lease-number field. Therefore, any lease number greater than 5 characters had a "?" in the fifth lease-number character field (fig. C-7B). An underlined lease number indicated that the complete lease number was not drawn on the map, but could be obtained from the well card; a "?" was added to the lease number to indicate uncertainty (fig. C-7C). If part of a lease number was unreadable (fig. C-7D), a "?" was added to the lease number. Finally, if an

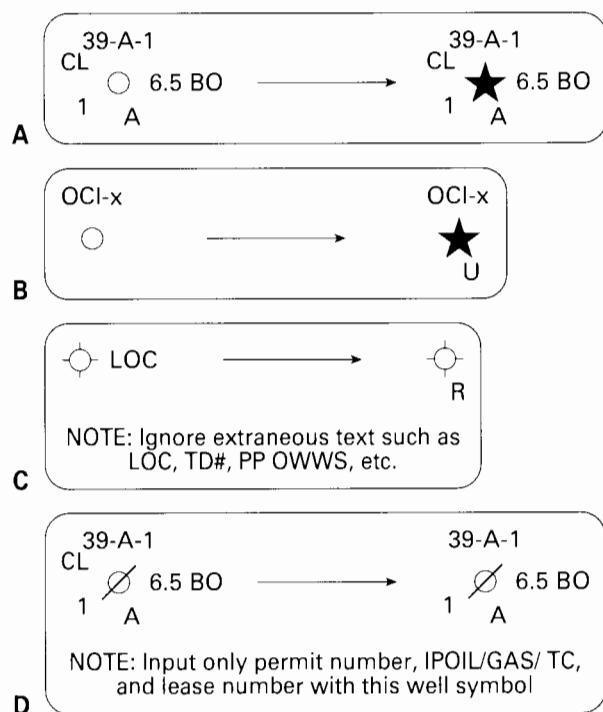


FIGURE C-4.—Illustration of capture rules for permitted and expired-permitted well symbols provided to the digitizing operators. See Appendix C for a further explanation of the figure.

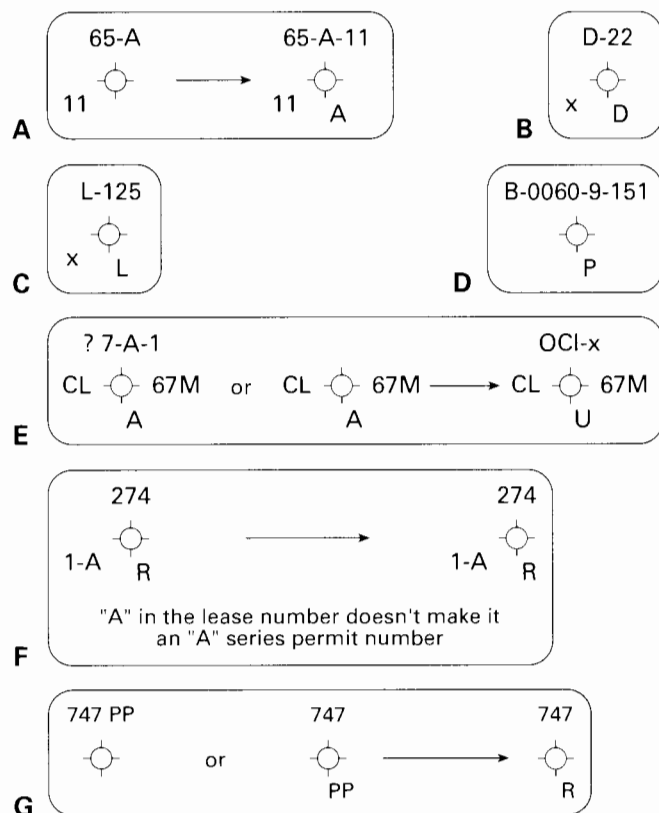


FIGURE C-5.—Illustration of the capture rules for permit numbers provided to the digitizing operators. See Appendix C for a further explanation of the figure.

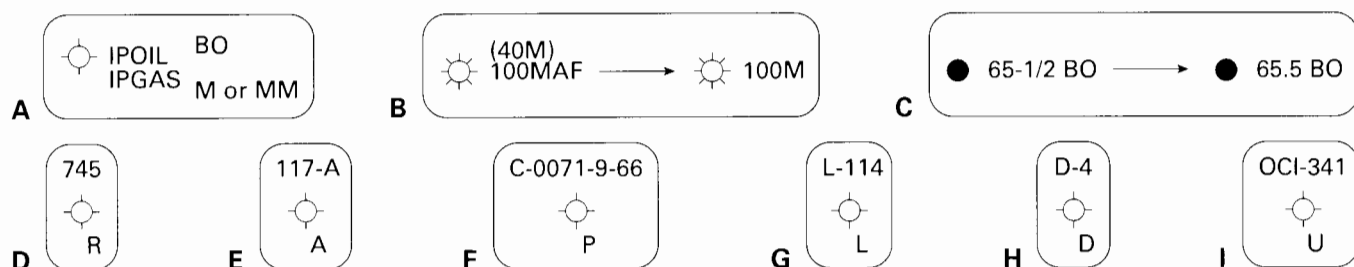


FIGURE C-6.—Illustration of capture rules for initial production and permit-type code provided to the digitizing operators. See Appendix C for a further explanation of the figure.

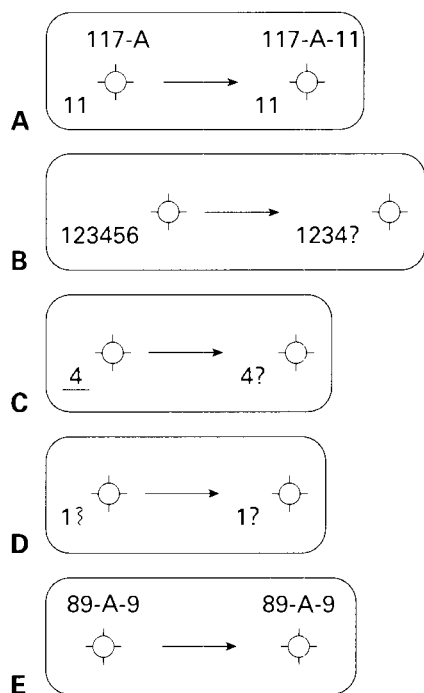


FIGURE C-7.—Illustration of capture rules for lease numbers provided to the digitizing operators. See Appendix C for a further explanation of the figure.

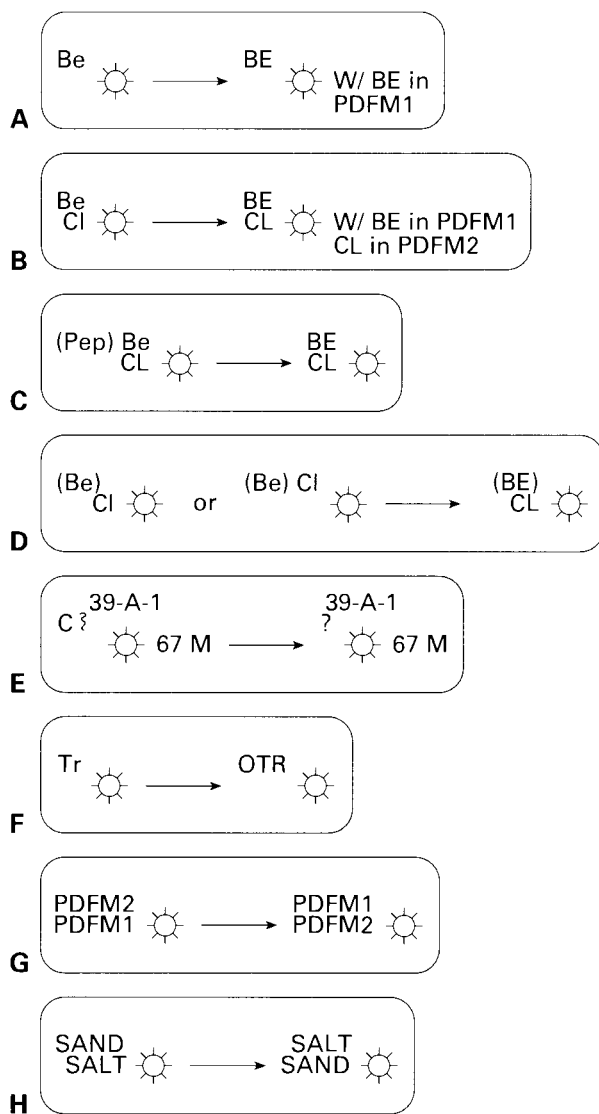


FIGURE C-8.—Illustration of the capture rules for producing formation provided to the digitizing operators. See Appendix C for a further explanation of the figure.

**APPENDIX D.—Additional editing rules that were applied after the data
were accepted from Ohio Penal Industries**

Rules for editing wells

1. If a well has more than one regular permit number, use only the lowest number.
2. Change plugged oil and/or gas shows to dry holes with the appropriate show.
3. Put the following miscellaneous abbreviations into the PDFM1 field if no formation is given. If there is more than one of the following on the well, use the miscellaneous abbreviation reflecting the well's most current status.

Abbreviation	Well type	Symbol
AI	Air Injection Well	Change symbol to injection well
DSPWELL	Disposal Well	Change symbol to injection well
DWELL	Domestic Well	Keep symbol from original map
ERP	Enhanced Recovery Project	Change symbol to injection well
GI	Gas Injection Well	Change symbol to injection well
IW	Injection Well	Change symbol to injection well
IWDW	Industrial Waste Disposal Well	Change symbol to injection well
LH	Lost Hole	Keep symbol from original map
OWELL	Observation Well	Keep symbol from original map
SMP	Solution Mining Project	Change to open circle
STEST	Stratigraphic Test	Change symbol to dry hole
STOR	Storage Well	Keep symbol from original map
SW	Salt Water	Change symbol to injection well
SWDW	Salt Water Disposal Well	Change symbol to injection well
SWIW	Salt Water Injection Well	Change symbol to injection well
WI	Water Injection	Change symbol to injection well
WF	Water Flood Well	Change symbol to injection well
WWELL	Domestic water well	Change to open circle

- a. If a formation is given, put the formation into PDFM1 and the miscellaneous abbreviation into PDFM2.
- b. If more than one formation is given, put the miscellaneous abbreviation into PDFM2. Put the deepest formation that is currently producing oil and gas into PDFM1 unless there is notation around the well indicating otherwise.
- c. If "lost hole" is marked on any of the other well types, put the miscellaneous abbreviation in PDFM1, LH in PDFM2, and leave off any formations listed.
4. For wells converted from existing wells:
 - a. Show symbol of the current well type.
 - b. Keep old text but put it in parentheses if there is a field(s) available.
 - c. If the miscellaneous abbreviations in Rule 3 are in parentheses on the original map, keep the symbol as it is on the map and put the miscellaneous abbreviation in parentheses into PDFM1 if no formation is given.
 - i. If a formation is also given, put that into PDFM1 and the miscellaneous abbreviation into PDFM2.
 - ii. If more than one formation is given, drop the miscellaneous abbreviation and put the two deepest formations that are currently producing oil and gas into PDFM1 and PDFM2, respectively.
5. Wells in subdivisions with boundaries along a river, shoreline, etc.: If the boundary has moved and the well location has changed, measure the well location directly from the mylar to the nearest corner of the subdivision not along the waterway. Spot this location on the paper plot and move the digitized well accordingly.
6. Other numbers around wells that begin with a letter, e.g., D-500, H-1186, L-1047, WF-9:
 - a. If the well with a lettered identification number has a permit number, use the permit number. Drop the lettered identification number (do not put it in the lease number field either).
 - b. If the well has no permit number, put the lettered identification number in the permit number field and assign type codes as follows:

Lettered #	Type code
D	D
H	H
L	L
WF	W

Resolving discrepancies

- Q1. What goes into PDFM1 and PDFM2 for wells producing from more than two horizons?
- A1. Use stratigraphically youngest and oldest formations.
- Q2. What goes into PDFM1 and PDFM2 for wells with specific production information for more than one producing horizon? e.g. BE—5BO, CL—10BO
- A2. Use stratigraphically youngest and oldest formations in PDFM's and total the production info of all formations for IPOIL and IPGAS.
- Q3. What goes into PDFM1 and PDFM2 if a well is labeled as more than one type, e.g., "SWDW and SWIW5"?
- A3. Put both SWDW and SWIW into PDFM1. If there is also a formation listed, put the formation into PDFM1 and the other text into PDFM2.
- Q4. What symbol and text should be used if an expired permit symbol says "Dry Hole" or "Lost Hole"?
- A4. Check records at Division of Oil and Gas or ODGS. Change to the most recent status.
- Q5. What goes into IPOIL and/or IPGAS for wells with production information for specific length of time, e.g., "5BO in 1st 6 hours" or 50M in 1st 48 hrs?
- A5. Convert to BO (per day) for oil and M (per day) for gas.
- Q6. What goes into IPOIL and/or IPGAS for wells with nonstandard production information, e.g., "5gal?"
- A6. Ignore such text.
- Q7. What goes into PDFM field if a well was converted to an injection well but never used as such?
- A7. Use most recent classification regardless.
- Q8. What goes into PDFM if a well says, "not plugged" or "re-open?"
- A8. Check records at Division of Oil and Gas or ODGS and change to most recent status. If there is no IP or plugging report, change symbol to a star, put any old information in parentheses, and put REOPEN or NOPLUG in PDFM2.
- Q9. What goes into PDFM field if a well says "service well?"
- A9. Ignore such text.
- Q10. What goes into PDFM if a well says "Methane, landfill gas?"
- A10. Put LANDFILL in PDFM1 (or in PDFM2 if a formation is also listed).
- Q11. What goes into PDFM if a well has more than one formation listed?
- A11. Put the stratigraphically youngest and oldest formations that are currently producing oil and gas into PDFM1 and PDFM2. If one formation is currently producing oil and gas and the other formations are plugged back, list the formation that is currently producing oil and gas and the stratigraphically oldest plugged formation. If one formation is currently producing oil and gas and others are drilled deeper, list the formation that is currently producing oil and gas and the stratigraphically youngest drilled-deeper formation.
- Q12. What goes into PDFM if a well says "Gas at 400 ft?"
- A12. Ignore such text.
- Q13. What goes into PDFM if a well says "Core #..." or Sample #...?"
- A13. Ignore such text.

APPENDIX E.—Procedures for updating oil and gas well-card files and township well-location maps

Individual well cards are to be checked against the township well-location maps. In order to do this, the old digital well-spot map (ODM) will need to be pulled, the new digital well-spot map (NDM), and (if necessary) the old, original hand-spotted (mylar or linen) township map. The NDM will have the new 20000 and 60000 permit numbers on them. These new numbers are the new permit numbers, printed on the labels that must be put on all cards.

If wells are encountered that do not fit any of the scenarios below, or any other questions arise, bring them to Mr. Garry Yates, Head, ODGS Geologic Records Center or Mr. Joe Wells, Database Administrator, ODGS Petroleum Geology Group.

Pull the township maps (or have them plotted), pull the whole township card file (or those subdivisions that can fit in a box), and place into a cardboard drawer/box. Because the card file is organized by subdivision it will work to ODGS' advantage to do the work by section or lot.

1. When the maps, well cards, and new permit labels are obtained, the process may start. Pull all the cards for a section or lot from the cardboard drawer/box.
2. Work through each subdivision matching each well card to a well spot. When the mapped well spot is matched with the correct well card, place a label on the well card corresponding to the new permit number on the NDM, then highlight the corresponding well spot on the NDM with a **YELLOW** marker. In working with the 60000 series numbers, some research will have to be done to find these wells on the maps. Some 60000-series wells may be easy to find using the ODM to look for nonregular permit numbers (Pepper, "A," etc.) and then matching that well on the ODM with the same well on the NDM to get the correct 60000 number. Some wells may have to measured on the map and match measurements from

well cards. IPs and lease numbers can be used to help to make a final judgement.

3. Well spots may be encountered that do not have corresponding well cards. In these cases, highlight the well on the NDM with a **PINK** marker.
4. If a well spot does NOT have the correct permit number from the corresponding card, highlight the well spot in **GREEN** and write the correct permit number next to the well. DO NOT put a label on the well card. Keep a copy of the original well card with the NDM and place the original back in the main file in the front of the appropriate subdivisions card section.
5. Some well cards may have no corresponding locations on the maps. These will fall into two groups:
 - a. If the card has a regular permit number: using a scale, plot the location according to the footage call, place the appropriate symbol on the map, and highlight in **BLUE**. Keep a copy of the well card with the NDM. In areas of very dense drilling, quite a few wells may be found that have records in the files, but are not on the maps, because the scale of the map is not sufficient to show all wells. Again, for any cards that have regular permit numbers, label the cards properly and make a note on the map that additional locatable wells are found in this area.
 - b. If a well card has an older permit number (A, Pepper, etc.) or no permit/ID number, place the original card in the NOT LOCATED card section.
6. Upon completion of the checking process, every well spot on the NDM should be highlighted in some color. If not, a well has been missed. Finally, after a township has been completed the cards will need to be re-ordered (This might be done as each subdivision is completed). Cards for each subdivision should be in numerical order, but the 60000 series is to be followed by the 20000 series.

APPENDIX F.—List of acronyms

AF	After fracture	MCFG	Thousand cubic feet of gas
API	American Petroleum Institute	MCI	Marion Correctional Institute
BE	Berea Sandstone	MMCFG	Million cubic feet of gas
BO	Barrels of oil	NDM	New digital map
CAD	Computer aided drafting/computer aided design	OC	Orient Correctional Institute
CL	"Clinton" sandstone	ODGS	Ohio Division of Geological Survey
DLG	Digital line graph	ODM	Old digital map
DGN	Design file	ODOT	Ohio Department of Transportation
DMRM	Ohio Division of Mineral Resources Management	OPI	Ohio Penal Industries
GIS	Geographic information system	PLSS	Public Land Surveying System
GISOM	Generating Information from Scanning Ohio Maps	PP	Permit to plug
IP	Initial production	PUCO	Public Utilities Commission of Ohio
LJB	Lockwood, Jones, and Beals, Inc.	RBDMS	Risk-Based Data Management System
LOC	Uncertain location	TIGER	Topologically Integrated Geographic Encoding and Reference
IGDS	Interactive graphics design software	RMSE	Root mean square error
		USGS	U.S. Geological Survey

Front cover: Portion of the new oil- and gas-well township-location map for Knox Township, Columbiana County, Ohio.

Back cover: Portion of the old oil- and gas-well township-location map for Knox Township, Columbiana County, Ohio.



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